

[COMMITTEE PRINT]

**SPACE ACTIVITIES OF THE UNITED STATES,
SOVIET UNION AND OTHER LAUNCHING
COUNTRIES/ORGANIZATIONS: 1957-1990**

R E P O R T

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LETTER OF SUBMITTAL

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY,
Washington, DC, September 18, 1991.

Members of the Committee on Science, Space, and Technology

I am pleased to submit herewith this report entitled, "Space Activities of the United States, Soviet Union and Other Launching Countries/Organizations: 1957-1990" by Marcia S. Smith. It reviews and compares major accomplishments by the United States and the Soviet Union in the areas of space applications, space science, manned space programs and military applications. The report also includes an examination of space activities of other launching countries such as China, the European countries, India, Israel and Japan.

This document will have continuing value to the committee and the government as an authoritative summary of man's activities in space.

Sincerely,

GEORGE E. BROWN, Jr.,
Chairman.

CRS Report for Congress

Space Activities of the United States, Soviet Union and Other Launching Countries/Organizations: 1957-1990

Marcia S. Smith
Specialist in Aerospace Policy
Science Policy Research Division

July 31, 1991



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SPACE ACTIVITIES OF THE UNITED STATES, SOVIET UNION AND OTHER LAUNCHING COUNTRIES/ORGANIZATIONS: 1957-1990

SUMMARY

Since the first satellites were orbited by the Soviet Union and the United States in 1957 and 1958, several other countries have followed suit and developed their own abilities to launch satellites. In 1988, Israel became the most recent member of the space launching countries, joining China, Europe, India, and Japan. (Britain and France each developed their own launch vehicles during the 1960s, but later joined the European Space Agency and helped develop ESA's Ariane booster, so they do not count as launching countries now.)

Over the past 33 years, satellites have become commonplace for applications such as communications, navigation, and weather forecasting and other forms of remote sensing of the Earth. Both the military and civilian sectors utilize these types of satellites, and the military aspects are generally not controversial. In recent years, concern has grown about the possible "weaponization" of space, but to date, no country has based weapons in space. Both the United States and Soviet Union have developed antisatellite weapons to enable them to destroy each other's space assets in times of crisis, although neither side has used them against the other's satellites. Today, the U.S. Department of Defense considers one Soviet ASAT system to be operational (though it has not been tested since 1982), while the U.S. does not have an operational ASAT system.

In the fields of science and exploration, spacecraft have also become familiar. Probes have visited Mercury, Venus, Mars, Jupiter, Saturn, Uranus, and Neptune. Spacecraft have studied comets at close range, and observatories in Earth orbit study the universe in wavelengths that cannot penetrate Earth's atmosphere, adding considerably to scientific understanding of cosmology. Other satellites study interactions between the Sun and Earth.

The superpowers launched a total of 241 individuals into space through the end of 1990, representing 21 countries, and twelve Americans have walked on the surface of the Moon. Today, the United States has a space shuttle and is building a space station (it had one in 1973-1974), while the Soviets are operating their seventh successful space station and have tested their own shuttle once (without a crew aboard).

In the United States, space activities have enjoyed considerable support, although budget constraints complicate long range planning. The U.S. Government will spend approximately \$34.8 billion on space in fiscal year 1991 (\$13.9 billion for NASA; approximately \$0.5 billion for other civilian agencies; and \$20.4 billion for DOD).

Where possible, information in the text has been updated through May 1991; data in the tables are current through December 31, 1990. Detailed discussion of many of the policy issues identified in this report can be found in related CRS products referenced herein.

TABLE OF CONTENTS

INTRODUCTION	1
SUMMARY OF RECENT ACTIVITIES	2
United States: Progress	
Accompanied by Nagging Problems	2
Hubble, Shuttle and Space Station Troubles	3
The Augustine Report	4
Satellites and the Persian Gulf	4
Soviet Union: A Future in Doubt	5
China	7
European Space Agency/Arianespace	7
Japan	8
India and Israel	9
STATISTICAL DATA ON LAUNCHES: 1957-1990	9
 PART ONE: U.S. AND U.S.S.R. SPACE ACTIVITIES	15
 CHAPTER 1: INTRODUCTION	15
 CHAPTER 2: HUMAN SPACEFLIGHT	17
SHOOTING FOR THE MOON	17
Early Flights: 1961-1966	17
1967: Double Tragedies	18
The United States Wins the Moon Race	18
DETENTE IN SPACE: THE APOLLO-SOYUZ	
TEST PROJECT (ASTP)	19
SPACE STATIONS	19
Soviet Space Stations	19
The First Generation: Salyut 1-5	19
The Second Generation: Salyut 6 and 7	21
Third Generation: Mir ("Peace")	23
1986-1987	25
1988-1990	25
U.S. Space Stations	28
Skylab	28
The U.S./International Space Station "Freedom"	28
Future Space Stations	31
REUSABLE SPACE VEHICLES	32
The U.S. Space Shuttle	32
The Challenger Tragedy	32
Pre-Challenger Shuttle Missions	32
Return to Flight	34
Aerospace Plane	34
Soviet Space Shuttle	35

CHAPTER 3: SPACE APPLICATIONS FLIGHTS	55
COMMUNICATIONS	55
NAVIGATION	57
GEODESY AND MAPPING	58
SEARCH AND RESCUE	58
METEOROLOGICAL SATELLITES	59
REMOTE SENSING	59
MISSION TO PLANET EARTH AND THE EARTH OBSERVING SYSTEM	61
CHAPTER 4: SPACE SCIENCE	63
EARTH-ORBITAL SPACE SCIENCE	63
AUTOMATED LUNAR EXPLORATION	64
U.S. PLANETARY MISSIONS	66
SOVIET PLANETARY MISSIONS	67
FUTURE U.S. AND SOVIET SPACE SCIENCE MISSIONS	69
CHAPTER 5: MILITARY SPACE ACTIVITIES	71
MILITARY VERSUS CIVIL SPACE MISSIONS	71
MILITARY SPACE PROGRAMS	71
SPACE WEAPONS	74
Early U.S. and Soviet Antisatellite Programs	75
The Soviet Co-Orbital ASAT Device	75
U.S. F-15 Miniature Homing Vehicle ASAT Device	75
Other Antisatellite Devices	76
Soviet Fractional Orbital Bombardment System (FOBS)	77
CONCERNS ABOUT THE MILITARIZATION OF SPACE AND "STAR WARS"	77
CHAPTER 6: SPACE PROGRAM MANAGEMENT AND RESOURCES	79
SPACE EXPENDITURES OF THE U.S. AND U.S.S.R.	79
MANAGEMENT OF SPACE PROGRAMS	79
LAUNCH SITES	81
LAUNCH VEHICLES	82
CHAPTER 7: FUTURE DIRECTIONS	89
THE NATIONAL COMMISSION ON SPACE AND RIDE REPORTS	89
Pioneering the Space Frontier	89
Leadership and America's Future in Space	91
PRESIDENT BUSH'S "SPACE EXPLORATION INITIATIVE"	92
LONG-TERM SOVIET PLANS	93
COOPERATION BETWEEN THE UNITED STATES AND SOVIET UNION	94
CHAPTER 8: TABLE OF SPACE "FIRSTS"--U.S. AND SOVIET	97

XI

PART TWO: SPACE ACTIVITIES OF OTHER LAUNCHING COUNTRIES/ORGANIZATIONS	103
CHAPTER 1: CHINA	105
DEVELOPMENT OF THE CHINESE SPACE PROGRAM	106
COMMERCIAL LAUNCH SERVICES	106
OTHER DOMESTIC AND INTERNATIONAL SPACE ACTIVITIES	108
FUTURE PLANS	109
CHAPTER 2: EUROPEAN SPACE AGENCY AND ARIANESPACE ..	113
ARIANE AND ARIANESPACE	113
ARIANE 5, COLUMBUS AND HERMES: ESA'S MAJOR INITIATIVES FOR THE 1990s	114
SPACE SCIENCE AND APPLICATIONS	115
COOPERATION WITH THE UNITED STATES AND SOVIET UNION	116
FUTURE ESA PROGRAMS	117
CHAPTER 3: INDIA	121
CHAPTER 4: ISRAEL	125
CHAPTER 5: JAPAN	127
SPACE SCIENCE AND APPLICATIONS PROGRAMS	128
HUMAN SPACEFLIGHT ACTIVITIES	130
COOPERATION WITH THE UNITED STATES AND SOVIET UNION	131

SPACE ACTIVITIES OF THE UNITED STATES, SOVIET UNION AND OTHER LAUNCHING COUNTRIES/ORGANIZATIONS: 1957-1990

INTRODUCTION

During the first era of space activities, only the United States and the Soviet Union had the ability to place satellites in Earth orbit or send them off to distant planets. As early as 1965, this monopoly was challenged by France, but the launch vehicle it developed could only orbit very small payloads, and its use ended ten years later. Britain also developed its own launch vehicle, but it was used only twice. Both Britain and France later joined with nine other European countries to form the European Space Agency (ESA), which now has a launch vehicle called Ariane. Four other countries--China, India, Israel, and Japan--also have independent launch capabilities.

This report summarizes the programs of the United States, Soviet Union, and the other "launching" countries. Launches by commercial companies are included with the country where the company is headquartered; Arianespace (a French company) is addressed together with ESA. A statistical summary of launches and payloads since 1957 is shown in tables 1 and 2.

CRS has prepared several other reports on space activities which the reader may wish to consult for further information. A series of studies entitled *Soviet Space Programs* has been prepared for the Senate since the early 1960s. The most recent edition, covering 1981-1987, is available from the Senate Commerce, Science and Transportation Committee. *United States Civilian Space Programs 1958-1978 (Volumes I and II)* was written for and published by the House Science and Technology Committee in 1981 and 1983. *World-Wide Space Activities*, which provides detailed information on the space activities of all countries in the world except the United States and Soviet Union, was prepared for and published by the House Science and Technology Committee in 1977. CRS Report 84-127, *Space Activities of the Non-Launching Countries*, updates information on countries which use space but do not have an indigenous launch capability. Several CRS issue briefs are also available on specific space topics and are referenced herein.

This report has been revised and updated by Marcia S. Smith, Specialist in Aerospace Policy. Mr. Geoffrey Perry, M.B.E., head of the Kettering Group in England, provided some of the data for the tables and other information. The report is based on analysis of information contained in the numerous, unclassified sources cited in the above committee prints, and on earlier editions of this report written by the late Charles S. Sheldon II, formerly a Senior Specialist in Space and Transportation. Detailed citations are omitted for the purpose of keeping this as brief as possible. The most frequently used sources, however, are publications of the Foreign Broadcast Information Service (FBIS)

and trade publications such as *Space News*, *Aviation Week and Space Technology* and *Aerospace Daily*.

SUMMARY OF RECENT ACTIVITIES

As shown in table 1a, the total number of launches in the world during 1990 was 116, the same as in 1988, but 15 more than 1989. The two primary reasons for the increase over last year were more launches by the United States (27, compared to 18 in 1989), and a total of 6 launches by two countries that had none in 1989 (China and Israel).

The Soviet Union continues to launch more often than any other country, with a total of 75 launches in 1990 (one more than last year). Overall, however, the Soviet launch rate has declined in the past few years, primarily because of better technology so satellites have longer lifetimes.

The United States completed 27 launches, the most in a single year since 1985. China had a record number of launches in 1990--five, compared to none in 1989 and a typical annual launch rate of one or two. Japan completed three launches, one more than in 1989, while Europe had five, two less than the previous year due to a launch vehicle failure in February that delayed flights for five months. Israel had one launch. India conducted no space launches; its last two (in 1987 and 1988) were failures.

United States: Progress Accompanied by Nagging Problems

During 1990, there were 27 U.S. launches, the most since the triple launch vehicle failures of 1986 (the space shuttle, Titan and Delta), and an increase of nine over last year. Among the launches were six of the space shuttle, fewer than planned because the shuttle was grounded for five months after hydrogen leaks were discovered in two of the three orbiters (see below).

Four of the six shuttle flights were civilian missions: three for space science (deployment of the Hubble Space Telescope and of the Ulysses probe to study the Sun, plus a Spacelab mission for astronomy called ASTRO-1), and one to deploy a communications satellite and retrieve the Long Duration Exposure Facility. Ten of the other U.S. launches were for civilian purposes, primarily communications (many of which were commercial). One of these used a new privately-developed expendable launch vehicle (ELV) called Pegasus which is launched from a B-52 airplane (it carried two experimental satellites, one for NASA and one for the Defense Advanced Research Projects Agency--DARPA); in this report it is counted as a civilian launch. Separately, the Magellan spacecraft, launched in 1989, reached Venus and sent back detailed radar information on the surface of that planet. Initial problems encountered with the spacecraft were overcome by ground controllers.

Department of Defense (DOD) satellites accounted for the other two shuttle missions, and the remaining 11 ELV launches in 1990. Five of the DOD

launches orbited Navstar Global Positioning System (GPS) navigation satellites. Eighteen satellites are needed for a complete system, and DOD hopes to have Navstar GPS completely operational in 1992 (it was used extensively in support of allied forces in the Persian Gulf War even though it is not completed). Other DOD satellites launched in 1990 reportedly were for photo reconnaissance, electronic intelligence, early warning, communications, weather, a test for the Strategic Defense Initiative Organization, and a separate set of three test satellites. Military satellites in general played a strong role in support of the Persian Gulf forces (see below).

Hubble, Shuttle and Space Station Troubles

While 1990 heralded a number of successes for NASA and the U.S. civilian space program, nagging problems arose with three major NASA programs. The Hubble Space Telescope, launched via the space shuttle in April, was discovered to have a flawed primary mirror which significantly reduced the amount of data astronomers can obtain with the instrument. Hubble is the first telescope in orbit designed to view objects in the visible wavelengths; it also carries ultraviolet sensors which are unaffected by this problem. Hubble is returning excellent data in the ultraviolet range, and of bright objects in the visible range, but one of its primary missions was to see very faint objects at great distances. The flaw in the mirror, which scientists say could have been detected prior to launch if an end-to-end test had been conducted of the entire telescope, makes distant, faint objects too blurry. NASA is developing plans to repair Hubble on a shuttle flight in 1993 or 1994 by installing equipment to compensate for the mirror's defect.

At the same time the Hubble problems arose, hydrogen leaks in two of the three space shuttle orbiters grounded shuttle flights for five months, and questions arose about the design of the U.S./International Space Station *Freedom* which NASA plans to launch in the mid-1990s. NASA can be credited for delaying space shuttle launches until engineers were certain that the leaks had been fixed, but the hiatus highlighted the vulnerability of the shuttle system to unexpected delays. This is especially important in the context of the space station program, since the station will be completely dependent on the shuttle for construction and operation. Questions about the space station's design already had garnered headlines in a series of articles in the *New York Times* concerning the amount of extravehicular activity (EVA, or spacewalks) that would be required to assemble and maintain it in orbit, the fact that it was overweight, and the increasing amount of electricity that would be required for "housekeeping" functions meaning a reduced amount of power for experiments.

Congressional concerns about the space station design led to language in NASA's FY1991 appropriations bill (P.L. 101-611) requiring NASA to restructure the program to reduce costs, and make each phase of the station independent of other phases. A restructuring plan was submitted to Congress in March 1991. The cost through 1999 was reduced to \$30 billion (from \$38.3 billion) primarily by reducing the size of the two U.S. modules by about 40 percent, reducing the amount of electricity that will be generated, and slipping

the date when the station will be permanently occupied (PMC or permanently manned capability) from 1997 to 1999 and hence pushing most of the operations costs past 1999. Crew size was reduced from eight to four. NASA hopes to restore the station to its original capability in the post-2000 time frame if budgets permit.

Two advisory bodies (the White House Office of Science and Technology Policy, and the National Academy of Sciences Space Studies Board) criticized the plan because it would permit so little science to be conducted, though both agreed that there are other reasons for building a space station than scientific experiments. The Bush Administration's position is that space station is needed to demonstrate U.S. leadership in space and as part of the Space Exploration Initiative to return humans to the Moon and then go on to Mars (also called "the Moon/Mars program" or "Mission from Planet Earth").

The Augustine Report

Concerns about the Hubble, shuttle and space station prompted the White House to strongly encourage NASA to establish an outside advisory panel to review NASA's programs and management. Chaired by Norman Augustine, chairman and CEO of Martin Marietta Inc., the panel's report was published in December 1990 (*Report of the Advisory Committee on the Future of the Space Program* or "the Augustine report") and has been the subject of several congressional hearings.

The Augustine committee recommended that NASA's budget increase by 10 percent real growth per year and that the agency conduct a balanced space program. In the event such budget increases were not available, however, the report (amplified by testimony to congressional committees) prioritized NASA's programs as follows: space science, which should continue to be funded at its current level of approximately 20 percent of NASA's total budget; the Mission to Planet Earth program of environmental satellites; a new heavy lift launch vehicle; funding for technology development; and Mission from Planet Earth, a name the committee coined for the Moon/Mars program to demonstrate its complementarity with Mission to Planet Earth). Since the space station is now being justified as part of Mission From Planet Earth, and MFPE is the last priority, some observers have questioned whether the space station should have such a high priority in NASA's funding. Congress is debating that issue in the context of NASA's FY1992 budget request.

Satellites and the Persian Gulf

Although NASA's space activities are the most visible, the United States also has a large military space program. In fact, DOD spends more on space programs than NASA (\$20.4 billion for FY1991 compared to \$13.9 billion for NASA). The utility of military satellites for warfare was clearly demonstrated during the Persian Gulf war. Beginning with Iraq's invasion of Kuwait on August 2, 1990, DOD made extensive use of satellites to cope with the situation in the Persian Gulf. This was the first "space war" where a diverse array of

satellite assets were available for everything from intelligence gathering to communications and navigation. Among the U.S. military satellite systems used extensively, were those for early warning of Scud missile launches (the Defense Support Program--DSP); communications (Defense Satellite Communication System--DSCS, Fleet Satellite Communication--FLTSATCOM, Satellite Data System--SDS, and Leasat); weather (Defense Meteorological Satellite Program--DMSP); navigation (NAVSTAR Global Positioning System--GPS); and photographic and electronic reconnaissance. (See CRS Report 91-215 SPR, *Military and Civilian Satellites in Support of Allied Forces in the Persian Gulf War* for further information.)

Space advocates within DOD were delighted at the chance to prove the value of their programs to the Services, since they believed that space programs often were on the losing end of internal Pentagon budget debates. How much the Persian Gulf experience will help justify new military space programs is an open question. The MILSTAR communications satellite system, and an Advanced Warning System for early warning, have both had budget difficulties recently. The MILSTAR program has been reduced in size at congressional insistence and redirected toward tactical (rather than strategic) communications; DOD chose not to request funding for the Advanced Warning System, opting instead to develop an improved version of the existing DSP system at what is expected to be much less cost.

Soviet Union: A Future in Doubt

The Soviet space program continued at an even pace during 1990 with no dramatic high or low points. Cosmonauts occupied the space station *Mir* throughout the year, and another module, *Kristall*, was added in the summer. It is specially designed for materials processing experiments.

One science mission was launched--Gamma, a Soviet/French gamma ray astrophysical observatory. The launch had been delayed since 1984. Satellites for communications, navigation, weather, and the usual array of military missions were also placed in orbit.

There still were no launches of nuclear reactor-powered Soviet radar ocean reconnaissance satellites (RORSATs). The last RORSAⁿ launch was in March 1988. The next month, communication was lost with a previously launched RORSAT (Cosmos 1900) and the Soviets waited tensely until October of that year to see if fail-safe systems aboard the satellite would correctly send the nuclear reactor section to the higher "safe" orbit used for these devices. The fail-safe systems worked, but the Soviets apparently have decided to reassess the design of (and perhaps the need for) these satellites. This was the third failure in the RORSAT program (the other two were Cosmos 954 in 1978 and Cosmos 1402 in 1983). The U.S. Department of Defense has cited RORSATs as a primary justification for building an antisatellite (ASAT) weapon (see part 1, chapter 5).

The Soviets continued attempts to commercialize space activities. Four commercial remote sensing missions (Resurs F-6 through F-9) were launched, two of which also carried materials processing experiments. One spacecraft just for materials processing (Foton 3) was also launched. The first Soviet commercial radar imaging satellite, Almaz, was scheduled to be launched in 1990, but was not launched until March 1991. Negotiations began between the United States and Soviet Union to purchase a Topaz 2 space nuclear reactor. A "museum" version of the reactor was sent to the United States for exhibition, but an actual reactor has not yet arrived. The U.S. Department of Defense's Strategic Defense Initiative Organization and the Department of Energy want to operate the Topaz 2 to determine if there is anything they can learn that would be applicable to U.S. attempts to develop a larger version of a space nuclear reactor (the Topaz 2 can generate 6 kilowatts (kw) of electricity while the United States is seeking to develop a 100 kw reactor).

Soviet efforts to sell commercial space launch services have not advanced very far since 1989. The Bush Administration released a new commercial launch vehicle policy in 1990, but the prohibition on launching satellites containing U.S. components on Soviet launch vehicles from within the Soviet Union did not change. The issue of launching on Soviet vehicles from outside the Soviet Union, specifically the Cape York proposal for an Australian company (Cape York Space Agency) to purchase Soviet launch vehicles and launch them from Cape York, Australia, is in limbo. The Bush policy approved participation of a U.S. company in the CYSA project, but with a number of conditions. One, which the Soviets have rejected, is that they not conduct commercial launches from inside the Soviet Union and use only one site outside. Additionally, CYSA's parent company, Essington Developments, experienced financial difficulties during 1990 and is seeking to sell CYSA.

The political future of the Soviet space program remains in doubt as the Soviet Union undergoes political and economic upheaval. Although the Soviets are much more open about the space program today, it is still almost impossible to understand clearly how much is being spent on space and exactly on what it is being spent. Revelations about past Soviet space programs--particularly the unsuccessful program to send cosmonauts to the Moon in the late 1960s--are becoming commonplace, but plans for future programs are murky. Rising dissent among the Soviet populace and some government officials against the space program is evidenced by complaints ranging from space spending as a waste of scarce government resources, to environmental damage to areas around Soviet launch sites from years of launch operations.

At greatest risk of cancellation or long term deferrals are the Soviet *Buran* space shuttle program and its *Energiya* launch vehicle. *Buran* has flown only once (in 1988), without a crew, and plans for its second flight (also without a crew) have been delayed from 1989 to 1990 to late 1991 or 1992. The first flight with a crew apparently now is not planned until 1995. The problem appears primarily to be one of budgets rather than technical difficulties. There is no clear need for the Soviet shuttle considering its cost. While the Soviet space station program would benefit from an inexpensive reusable spacecraft for

taking crews back and forth, *Buran's* large cargo bay seems superfluous since the Soviets have such a wide array of ELVs (the U.S. shuttle was built with the expectation that ELVs would be phased out, but the Soviets have stated they have no plans to phase out ELVs.) Similarly, *Energiya* is a launch vehicle without a mission. Its primary purpose was to launch *Buran*, larger space stations, and an array of futuristic missions like missions to Mars. The Soviet budget is not likely to permit initiation of most of these future programs for quite some time, however.

China

China had a record number of launches in 1990 (five), including its first commercial launch (*Asiasat-1*) and its first international cooperative launch (Pakistan's test amateur communications satellite *Badr-1*). The other three launches were for weather, communications, and science. Each of China's three launch sites were used during the year.

The issue of launching Western satellites on Chinese launch vehicles continued to be controversial. In order to win export approval for three satellites built by a U.S. company (Hughes Aircraft) so they could be launched in China, a bilateral U.S.-Chinese agreement was signed in 1989 which stated that, among other things, China would price launch services "on a par" with Western competitors. In 1990, however, China contracted with the Arabsat Consortium to launch a satellite for what Western observers considered to be well below "par." Charges and countercharges flew between China and Arianespace, the French company that markets the Ariane booster and which had competed against China for the launch. Ultimately, for reasons not yet fully explained, in 1991 the Arabsat Consortium terminated its agreement with China and signed a contract with Arianespace.

Dissatisfaction with internal Chinese policies in the aftermath of Tiananmen Square, along with concerns about protecting the U.S. launch services industry, has kept the issue of launching U.S.-made satellites on Chinese boosters on Congress' agenda. Existing language in the 1990-1991 Foreign Relations Authorization Act (P.L. 101-246) requires the President to certify to Congress that such launches are in the national interest when approving export licenses, and some Members are seeking to strengthen that language. Uncertainty about whether the United States would grant an export license for a satellite built for Indonesia (Palapa) apparently led the Indonesian Government to choose an American company (McDonnell Douglas) to launch the satellite instead of China.

European Space Agency/Arianespace

The European Space Agency (ESA) began facing what may be a challenging decade as some of its member countries experience budgetary pressures that may force changes in some future ESA programs. In addition to its standard program of scientific and applications satellites, ESA is embarking on three major programs: *Columbus*, part of the U.S./International Space Station

Freedom program (the *Columbus Attached Pressurized Module* that will be attached to the space station itself, plus two automated platforms for other experiments called the *Columbus Free-Flying Laboratory* and the *Columbus Polar Platform*); development of a spaceplane to take crews back and forth to space (*Hermes*); and a larger version of the Ariane launch vehicle (Ariane 5). Germany, straining under the weight of the costs of reunification, is seeking to reduce its monetary obligations to ESA, although it insists it will fulfill all its current commitments. Still, Germany is seeking to reduce the size of the *Columbus* module and divorce the free-flying platform from the space station program to make it less complex. ESA is expected to decide in the fall of 1991 whether to proceed with full scale development of these programs and on what schedule.

Trade negotiations with the United States over "rules of the road" for commercial launch services began in earnest in 1990 and are expected to continue through 1991. Issues involving fair pricing by U.S. and European firms, as well as the entry of "non-market economies" (China and the Soviet Union) into the market, are on the agenda.

Arianespace conducted 5 successful launches, fewer than planned because of a failure in February 1990 that caused the loss of two Japanese broadcast satellites. Launches were suspended for five months. The cause of the failure was discovered to be a small rag that was left in a water supply line to one of the engines.

To keep this report as brief as possible the activities of individual European nations in space are not included here. The reader should note that many of these countries, especially France, Germany and Italy, have substantial space programs in addition to their participation in ESA.

Japan

Japan's space program continued on its modest course through 1990. Development of the new H-2 launch vehicle experienced some technical problems (not unusual in a development program), and its first launch has been delayed by one year to 1993. Establishment of a company to build H-2 launch vehicles by 77 Japanese aerospace corporations, insurance companies and banks has fueled speculation that Japan plans to enter the commercial launch services market once the vehicle is operational. The Japanese have indicated only that commercial launch services are a long term (end of the decade) possibility. Plans to build a module for the U.S./International Space Station *Freedom* (JEM, the Japanese Experiment Module) also continued, although Japan has expressed concern about the reduction in crew size from eight to four in NASA's restructuring plan (see part 1, chapter 2) and received assurances from NASA that ultimately a crew of eight is planned, budgets permitting.

Japan encountered a few difficulties during 1990 and early 1991 concerning communications satellites. In February 1990, an Ariane rocket carrying two Japanese broadcasting satellites exploded shortly after launch. In April 1991,

an Atlas-Centaur rocket carrying a similar satellite failed and had to be destroyed. At the same time, one of the two existing Japanese broadcasting satellites already in orbit suffered a partial failure. Japan is now considering how to deal with this situation.

Also during 1990, a trade dispute was settled with the United States over whether foreign companies would be allowed to bid on communications satellites procured for the Japanese government or its quasi-governmental telecommunications agency (NTT). Japan had planned to build satellites that carried both operational and experimental equipment and decided that only Japanese firms could bid to manufacture the satellites. Filing under the Super 301 provisions of the trade act, the United States argued that it was an unfair trade practice to exclude U.S. companies from bidding to build operational satellites; there was no dispute over whether Japan could build its own experimental satellites. To satisfy U.S. concerns, Japan split the program into separate commercial and experimental satellites. The commercial satellites will be open for bidding to U.S. companies.

India and Israel

India had no launches in 1990. Israel conducted its second launch, which, like the first in 1988, was a test related to the development of reconnaissance and other types of satellites.

STATISTICAL DATA ON LAUNCHES: 1957-1990

The following tables provide data on total launch successes and failures and payload successes for all countries, and types of payloads launched by the United States and Soviet Union, from 1957 to the present. Footnotes explain some of the cautions to be observed in using the tables. For example, launch "success" indicates only that a payload achieved orbit, not that it achieved the intended orbit.

TABLE 1a. Worldwide Record of Successful Space Launches

Year	USSR	US	China	Japan	ESA	India	Israel	France*	Aust.*	UK*	Total
1957	2										2
1958	1	5									6
1959	3	10									13
1960	3	16									19
1961	6	29									35
1962	20	52									72
1963	17	38									55
1964	30	57									87
1965	48	63									112
1966	44	73						1			118
1967	66	58						1			127
1968	74	45						2	1		119
1969	70	40									110
1970	81	29	1	1							114
1971	83	32	1	2				2			120
1972	74	31		1				1			106
1973	86	23									109
1974	81	24		1						1	106
1975	89	28	3	2							125
1976	99	26	2	1				3			128
1977	98	24		2							124
1978	88	32	1	3							124
1979	87	16		2	1						106
1980	89	13		2		1					105
1981	98	18	1	3	2	1					123
1982	101	18	1	1							121
1983	98	22	1	3	2	1					127
1984	97	22	3	3	4						129
1985	97	17	1	2	3						120
1986	91	6	2	2	2						103
1987	95	8	2	3	2						110
1988	90	12	4	2	7		1				116
1989	74	18		2	7						101
1990	75	27	5	3	5		1				116
Total	2,255	932	28	41	35	3	2	10	1	1	3,308

* Note that France, Australia and the United Kingdom no longer launch their own satellites. France and the UK are members of the European Space Agency (ESA) which built the Ariane launch vehicle whose first launch was in 1979.

Italy conducted eight launches from 1967 to 1975, and one in 1988, using U.S. Scout rockets from the San Marco platform off the coast of Kenya. Since the launch vehicles were American, NASA includes them in U.S. launch statistics and they are treated the same way here.

Prepared by CRS.

TABLE 1b. Worldwide Record of Known Space Launches Failures

Year	USSR	US	China	Japan	ESA	India	Israel	France	Aust.	UK	Total
1957	*	1									1
1958	*	12									12
1959	*	10									10
1960	2	13									15
1961	*	12									12
1962	*	7									7
1963	*	8									8
1964	*	7									7
1965	*	7									7
1966	*	4		2							6
1967	*	3	*	1							4
1968	*	3	*		1**						4
1969	*	1	1	1	1**						4
1970	*	1	*	1	1**					1	4
1971	*	3	*		1**			1			5
1972	*	2	*								2
1973	*	2	*					1			3
1974	*	1	1								2
1975	2	3	*								5
1976	*		*	1							1
1977	*	2	*								2
1978	*	1	*								1
1979	*		1		1	1					3
1980	*	2	*								2
1981	2	1	*								3
1982	*		*		1						1
1983	1		*								1
1984	*		*								0
1985	1	1	*		1						3
1986	*	3	*		1						4
1987	1	1				1					3
1988	*		*			1					1
1989											0
1990	1				1						2
Total	10*	111	3*	6	9**	3	-	2	-	1	145*

This table shows launches that failed to attain orbit. Where an orbit was achieved, but it was an incorrect orbit that prevented a payload from achieving its mission, the launch is counted as a success, but the payload as a failure.

* It should be noted that both the Soviet Union and China rarely release information on failed launch attempts. In any launch vehicle development program failures can be expected, so it can be reasonably assumed that they have a similar success/failure ratio as the other launching nations.

** ESA, the European Space Agency, was formed in 1975 as the merger of the European Space Research Organization (ESRO) and the European Launcher Development Organization (ELDO). The 4 failures marked with a double asterisk under the ESA heading were part of ELDO's futile attempts to develop the Europa rocket. The 5 without asterisks are part of ESA's development and Arianespace's operation of Ariane.

Prepared by CRS.

TABLE 1c. Worldwide Record of Payloads Successfully Launched

Year	USSR	US#	China	Japan	ESA	India	Israel	France	Aust.	UK	Total
1957	2										2
1958	1	5									6
1959	3	10									13
1960	3	17									20
1961	8	35									43
1962	26	59									85
1963	20	62									82
1964	39	73									112
1965	76	97						1			174
1966	52	101						1			154
1967	75	88						2	1		166
1968	85	64									149
1969	80	66						3			149
1970	103	40	1	1				1			146
1971	114	54	1	2						1	172
1972	109	42									151
1973	130	26									156
1974	114	28		1							143
1975	140	35	3	2				4			184
1976	141	34	2								177
1977	125	29		2							156
1978	142	41	1	3							187
1979	126	18		1	1						146
1980	132	16		1		1					150
1981	148	20	3	3	5	1					180
1982	141	20	1	1							163
1983	138	30	1	3	3	1					176
1984	138	34	2	3	6						183
1985	140	35	1	2	5						183
1986	132	11	2	3	4						152
1987	121	11	2	3	3						140
1988	123	17	4	2	12		1				159
1989	114	25		2	10						151
1990	116	41	7	5	15		1				185
Total	3,157*	1,284	31	40	64	3	2	12	1	1	4,595

* Historically, statistics for Soviet payloads have included the orbital platforms used to send payloads into highly elliptical or geostationary orbits, or into planetary trajectories. Devices used by other countries for similar purposes historically have not been counted as extra payloads. A total of 404 platforms are included in the Soviet count. At a later date, they will be subtracted to make the Soviet figures consistent with the other countries.

The space shuttle is counted as one payload, regardless of what it carries. Satellites deployed from the shuttle are counted as additional payloads if they are left in orbit. Italy's payloads launched from the San Marco Platform are counted in the U.S. total since they were launched with U.S. rockets.

Prepared by CRS.

TABLE 2. Summary of U.S. and Soviet Payloads by Mission*

CATEGORY	UNITED STATES		SOVIET UNION	
	1990	1957-1989	1990	1957-1989
Platforms	--	--	21	383
Earth Orbital Science	4	194	1	197
Automated Lunar/Planetary				
Moon		25		34
Mercury		1		0
Venus		8		33
Mars		9		18
Outer Planets		4		0
Interplanetary Space		8		0**
Applications				
Communications	11	223	13	214
Weather	1	91	2	67
Geodesy		19	1	31
Earth Resources		7	5	73
Materials Processing		0	1	5
Piloted Activities				
Earth Orbital	6	51	3	72
Earth Orbital (Related)		13	5	105
Lunar		20		0
Lunar (Related)		17		8
Launch Vehicle Tests		11		21
Gen. Engineering Tests	7	28		4
Reconnaissance				
Photographic	1	243	17	740
Elint***	1	85	2	115
Ocean Elint	4	30	4	63
Early Warning	1	44	5	62
Minor Military		43	4	153
Navigation	5	60	10	147
Tactical/Theater Comm.		0	22	440
Weapons-Related				
FOBS***		0		18
Antisatellite Targets		2		18
Antisatellite Interceptors		0		20
Other Military		7		0
TOTAL	41	1,243	116	3,041

* Assignments are arbitrary to some extent and subject to revision each year as more information becomes available. This table is meant to provide only a general level of effort for each country and should be used cautiously.

** The Soviet VEGA probes which visited Venus and later Halley's Comet are included in the Venus total, rather than interplanetary probes.

*** Elint = Electronic Intelligence; FOBS = Fractional Orbital Bombardment System.

Prepared by CRS.



PART ONE**U.S. AND U.S.S.R. SPACE ACTIVITIES****CHAPTER 1****INTRODUCTION**

In 1955, both the United States and the Soviet Union announced their intentions to launch small scientific satellites as a contribution to the International Geophysical Year, a worldwide scientific effort from July 1, 1957, to December 31, 1958, designed to increase understanding of the Earth and of space physics. President Eisenhower, wanting to demonstrate the U.S. commitment to using space for peaceful purposes, initiated Project Vanguard to develop a "civilian" rocket (i.e., not based on missile technology) and a satellite weighing 14 kilograms. He would not allow the Army to launch a satellite even though it had the capability to do so in the fall of 1956.

Although it was known that the Soviets were also working on rocket technology, the world was startled when they launched the first satellite, Sputnik 1 (weighing 84 kilograms), on October 4, 1957. Few had expected that the "backward" Soviet Union would beat the scientifically advanced United States in this endeavor, and with a satellite many times heavier than what the United States was planning. Sputnik 2, launched on November 3, 1957, did not help the U.S. image: it weighed 508 kilograms, and carried a live dog, Laika. The first attempt to launch Vanguard, on December 6, 1957, ended in an embarrassing failure when it lifted three feet off the launch pad and came crashing back down in a fiery explosion. President Eisenhower finally relented and allowed the Army to use its missile technology to place an Army satellite (Explorer 1) in orbit on January 31, 1958. Vanguard ultimately succeeded in placing a satellite in orbit on March 17, 1958. These early satellites were designed simply to prove the principles of spaceflight, although scientists were able to extract useful information, too. For example, the early Explorer satellites led to discovery of the Van Allen belts of radiation which encircle the Earth.

Cold War tensions and U.S. embarrassment at being beaten by the Soviet Union placed the space program in the forefront of politics. The "Space Age" and the "space race" were virtually synonymous through the first decade of satellite launches. President Eisenhower, seeking to demonstrate that the United States was committed to the peaceful uses of space while simultaneously recognizing the importance of satellites to military objectives, submitted legislation to Congress that led to the creation of the National Aeronautics and Space Administration (NASA) on October 1, 1958, to manage the Nation's

civilian space program. Military space activities were assigned to the Department of Defense (DOD). This separation between military and civilian space programs continues to exist today (although other agencies now share responsibility for civilian space activities with NASA). NASA and DOD cooperate in some space programs (particularly launch vehicles, including the space shuttle), although their programs are conducted separately for the most part. Over the years, a variety of coordinating mechanisms have existed. Today, the White House National Space Council, chaired by Vice President Quayle, sets interagency space policy.

During the 1950s, 1960s and 1970s, the Soviet space program was shrouded in secrecy. The Soviets rarely announced the missions for which satellites were launched, and failures were unacknowledged. All that was known in the West about the organization of the program was that it was primarily run by the Strategic Rocket Forces. The exception was scientific programs which were developed through the various institutes of the Soviet Academy of Sciences, especially the Institute for Space Research (IKI). Today, the Soviet space bureaucracy is a muddy maze more impenetrable than ever. Secrecy is no longer the problem, but a proliferation of organizations with unclear divisions of labor. Glavcosmos, a department of the Soviet Ministry of General Machine Building, was created in 1985 to be a "civilian" space agency, but its influence appears to be waning as other parts of the space bureaucracy spread their wings. The military undoubtedly continues to have authority over specifically military space programs, and the Academy is still responsible for many scientific satellites, but who decides what experiments to fly on the *Mir* space station, the disposition of the results of those experiments, when to fly commercial remote sensing satellites, what hardware can be offered commercially to the West, and so forth, remains unclear. There is no evidence that the bureaucratic situation will improve in the near future. In fact, with the growing power of the Soviet legislature and its role in setting budgets, the question of who is deciding the fate of the Soviet space program may become increasingly difficult to answer.

CHAPTER 2

HUMAN SPACEFLIGHT

SHOOTING FOR THE MOON

Early Flights: 1961-1966

On April 12, 1961, Yuriy Gagarin became the first human to travel in space as he made one orbit of the Earth in Vostok 1. On May 5, Alan Shepard became the first American in space, although his Mercury-Redstone 3 (Freedom 7) flight was suborbital, lasting for only 15 minutes and landing about 480 kilometers downrange from Cape Canaveral.

Shepard's flight, even though it was suborbital, gave President Kennedy the confidence he needed to appear before Congress three weeks later, on May 25, 1961, to call upon the Nation to commit itself to the goal of landing a man on the Moon and returning him safely to Earth by the end of the decade. America accepted the challenge and the "Moon Race" was on, even though it was not until nine months later, on February 20, 1962, that John Glenn became the first U.S. astronaut to orbit the Earth.

The Soviet Vostok and U.S. Mercury flights were similar in purpose, and each country launched a total of six missions in their respective series. The flights demonstrated that humans could travel into space and return to Earth safely. The last of the Vostok flights took the first woman, Valentina Tereshkova, into space.

The Soviet Union followed its Vostok series with two flights of a modified version of that spacecraft, called Voskhod. On October 1964, Voskhod 1 carried the first three-man crew, and in March 1965, the Voskhod 2 mission included the first extravehicular activity (EVA) or spacewalk. The United States moved out quickly with the Gemini program in which 10 flights were conducted from 1965-1966 to increase the duration of the missions (up to 14 days), develop experience in rendezvous and docking procedures, and increase experience with EVAs (the first U.S. spacewalk occurred in June 1965).

While the United States conducted the Gemini flights, no Soviet piloted flights were made, and skepticism developed as to whether the two countries were in a race to the Moon or not. Since the Soviets conducted their space program secretly, it was difficult to determine their plans definitively, so accounts of Soviet planning relied on Western analysis and speculation. In 1989, however, the Soviets finally conceded that they had, in fact, intended to send cosmonauts to the Moon in the 1960s, but were unable to develop a Saturn V-class launch vehicle. (The Soviets finally introduced a Saturn-V class vehicle--

Energiya--in 1987). An interview with the man in charge of the design bureau for the launch vehicle, designated "N-1" by the Soviets but more widely known in the West as the "G" vehicle, confirmed Western reports that the vehicle had failed in its four launch attempts between 1969 and 1972. During 1990, more information was made available about what the Soviets had been planning, which was not substantially different from the route the United States chose to reach the Moon. The main difference was that only two cosmonauts would have travelled to the Moon, and one would have journeyed to the surface alone.

1967: Double Tragedies

In 1967, both countries were ready to introduce new piloted space vehicles--Apollo for the United States; Soyuz for the Soviet Union. The first missions for both of these vehicles ended in tragedy.

On January 27, 1967, the three-man crew of what was to have been the first Apollo flight--Gus Grissom, Ed White, and Roger Chaffee--were killed when a fire erupted in their Apollo spacecraft during pre-launch tests. Three months later, on April 24, 1967, Vladimir Komarov was killed in the first Soyuz flight when the craft's parachute lines became tangled during descent; he was killed upon impact with the Earth. Both programs were set back for a year and a half as they responded to safety concerns raised by the separate accidents.

The United States Wins the Moon Race

When the programs resumed in October 1968, it was clear that the United States was ahead in the Moon Race. The first U.S. flight (Apollo 7) was a full scale test of the Apollo command module in Earth orbit. The first Soviet flight (Soyuz 2 and 3) was a simple rendezvous between a piloted and an automated spacecraft, something that had been accomplished repeatedly in the U.S. Gemini program. In December 1968, three U.S. astronauts--Frank Borman, Jim Lovell, and Bill Anders--spent Christmas in lunar orbit. Their flight had been made possible by development of a special launch vehicle, the Saturn V, which was used to launch all the Apollo lunar missions.

On July 20, 1969, the United States officially won the Moon Race when Neil Armstrong and "Buzz" Aldrin became the first humans to set foot on the lunar surface, while Mike Collins orbited overhead. Through 1972, five more U.S. crews set foot on the lunar surface (Apollo 12, 14, 15, 16 and 17) returning 380 kilograms of lunar material to Earth for analysis. A sixth attempt, Apollo 13 in 1970, narrowly averted tragedy when the crew safely returned to Earth after an explosion in the service module.

Meanwhile, the Soviet Union continued a few automated flights to develop hardware for a human lunar mission (Zond 4-8 from 1968 to 1970, and apparently four Cosmos flights in 1970-1971), but lacking a launch vehicle with sufficient capability, they were unable to send people to the Moon and still have not done so, although they have retrieved lunar samples with automated probes.

Instead, they turned their attention to Earth orbit. In January 1969 they accomplished the first docking of two piloted ships (Soyuz 4 and 5) permitting crew transfer using EVA. Soyuz 6, 7, and 8 in October 1969 made a group co-orbital flight, although it is thought that two of the ships (Soyuz 7 and 8) were supposed to dock, but were unable to do so. In 1970, Soyuz 9 set what was then a duration record of 18 days. From that point, the Soviets began their very successful space station program described below.

DETENTE IN SPACE: THE APOLLO-SOYUZ TEST PROJECT (ASTP)

As a demonstration of detente, and as a spur to the development of a universal, androgynous docking system which would allow each country to rescue the other's astronauts, the United States and Soviet Union agreed to work cooperatively to conduct a joint flight, called the Apollo-Soyuz Test Project (ASTP), in which a three-man Apollo crew docked with a two-man Soyuz crew in 1975.

The Soviet Union agreed to a few modifications of the Soyuz spacecraft to permit this docking, and a test flight (Soyuz 16) was conducted in 1974. Both countries launched their ASTP spacecraft on July 15, 1975; the Soviet flight was designated Soyuz 19, while the U.S. flight has always been referred to simply as ASTP. The two ships docked on July 17, and undocked on July 19 after two days of exchange visits and joint experiments. Soyuz 19 returned to Earth on July 21; ASTP landed on July 24. Since ASTP was the last flight for the Apollo spacecraft, the androgenous docking adaptor became obsolete at the end of the mission from a U.S. perspective. The Soviets, however, have adapted its design for use on the *Mir* space station for eventual dockings of their space shuttle *Buran*.

SPACE STATIONS

Soviet Space Stations

The First Generation: Salyut 1-5

The world's first space station, *Salyut 1*, was placed in orbit by the Soviet Union on April 19, 1971. When docked with a Soyuz, it had about 100 cubic meters of interior space, compared to 275 cubic meters in the American *Skylab* space station (without the Apollo spacecraft) launched two years later.

The first attempt to occupy the space station failed when the Soyuz 10 crew was unable to enter the station after successfully docking with it. The Soviets then launched the three-man Soyuz 11 crew which became the first space station crew. They spent 24 days conducting medical, Earth resources, and astronomical experiments. Tragically, the crew was killed during their return to Earth on June 29, 1971. They had improperly closed a valve between two

sections of the Soyuz spacecraft, and when the sections separated during reentry, the spacecraft's atmosphere vented into space. The Soviets had long since given up the practice of requiring crews to wear spacesuits because of confidence in their hardware, so the three men—Georgiy Dobrovolskiy, Vladislav Volkov and Viktor Patsayev—were asphyxiated. Since this flight, all Soviet cosmonauts have been required to wear spacesuits during launch and reentry, and because the original Soyuz was unable to accommodate three space-suited crew members, the Soviets launched only two-man crews for the next ten years until the redesigned Soyuz T came into use.

The next two space station launches, *Salyut 2* and *Cosmos 557* in 1973, were failures. They were followed by two free-flying Soyuz missions (Soyuz 12, a diagnostic flight following the Soyuz 11 tragedy, and Soyuz 13, a piloted astronomical observatory).

Finally, in June 1974, the Soviets successfully orbited the next space station, *Salyut 3*. Western observers immediately noticed some interesting differences from *Salyut 1*: the crews sent to the station were all military instead of mixed military and civilian, when the crew entered the space station they switched to military telemetry, the orbit was lower (perhaps to improve picture resolution), and after it was unoccupied for a month, a data capsule was separated and returned to Earth in a manner similar to the return of photographic reconnaissance film. Therefore, this is counted in the West as the first military space station, optimized for reconnaissance activities. The Soviets stated that it was for Earth resources investigations. Of the two crews sent to *Salyut 3*, only one (Soyuz 14) was able to dock with it.

Salyut 4, launched December 26, 1974, was similar to *Salyut 1* and so is considered a civilian mission by Western analysts. Two crews docked with it (Soyuz 17 for 30 days and Soyuz 18 for 63 days), although a third (called the April 5th Anomaly or Soyuz 18A) was supposed to dock. In that case, a problem in the launch vehicle resulted in an abort which brought the crew back to Earth (unharmed) before reaching orbit. In November 1975, the automated Soyuz 20 docked with the station for a 90-day powered down test of the Soyuz spacecraft (biological specimens were carried for scientific experiments).

The next station, *Salyut 5*, was similar to *Salyut 3*, suggesting the Soviets had an alternating program of military and civilian space stations during this period. Two crews successfully occupied *Salyut 5* (Soyuz 21 for 46 days, Soyuz 24 for 18 days), while a third (Soyuz 23) was unable to dock.

Between the first two missions to *Salyut 5*, the Soviets launched another free-flying mission, Soyuz 22, which tested an East German multispectral camera (the MKF-6) for Earth resources studies. A modified version of the camera was installed on *Salyut 6* and 7.

The Second Generation: Salyut 6 and 7

On September 29, 1977, the Soviets launched a second-generation space station called *Salyut 6*. The most important improvement in the station was the addition of a second docking port at the aft end of the station which enabled resupply flights to dock with the station while a crew was on board. Flights of a new automated cargo ship, called *Progress*, began in 1978, and the first in-space fuel transfer took place between *Progress 1* and *Salyut 6* in January of that year. *Progress* is a modified Soyuz spacecraft and not designed to survive reentry, thus it can take supplies to a space station, but cannot bring anything back to Earth. The second port was also used for docking additional crews to occupy the station as visitors to the long-duration crew. This provided opportunities for taking supplies to the orbiting crew, and for bringing the results of the various experiments conducted on board back to Earth (which would otherwise have to wait until the main crew returned).

During its four and a half years in orbit, *Salyut 6* hosted 16 crews (2 others were unable to dock) which conducted a wide variety of Earth resources, materials processing, biomedical, and biological experiments (such as plant growth). The station was occupied for approximately 50 percent of the time it was in orbit.

During the *Salyut 6* period, the Soviets increased the duration for a crew in space to 185 days (the longest U.S. spaceflight is 84 days). The long duration crews would be visited by other crews who would remain for a week. Among the visiting crews were the first "international cosmonauts" representing the countries that belong to Intercosmos, the organization through which the Soviets cooperate with their allies. Cosmonauts from Cuba, Czechoslovakia, East Germany, Hungary, Mongolia, Poland, Romania, and Vietnam all visited *Salyut 6*. A Bulgarian was launched, but was not able to dock because the Soyuz 33 ferry craft malfunctioned. (The Soviets launched a Bulgarian in 1988 to the new *Mir* space station.)

A total of 12 *Progress* flights resupplied the crews, and three other automated missions (Soyuz 34, Soyuz T, and Cosmos 1267) docked with the station. Soyuz 34 was launched to replace the aging Soyuz 32 for returning the crew to Earth after the Soyuz 33 failure. Soyuz T was an automated test of a new version of Soyuz with upgraded avionics and other changes. The Soyuz T replaced the original Soyuz in 1981 and was used until it was replaced by another modified version, Soyuz TM, in 1986. Cosmos 1267 docked with *Salyut 6* in June 1981. The Soviets announced that its purpose was testing a modular space station concept, and that Cosmos 1267 had life support systems on-board. Later, *Aviation Week and Space Technology* reported that Cosmos 1267 was in fact a "battle station" in orbit, armed with infrared homing devices. *Salyut 6* and Cosmos 1267 were deorbited on July 29, 1982, while they were still docked. The full nature of Cosmos 1267's mission remains unclear, but probably was a modular space station test as the Soviets claimed.

Salyut 7 was launched on April 19, 1982, the eleventh anniversary of the launch of *Salyut 1*, and hosted crews intermittently through 1986. The space station was virtually identical to *Salyut 6*, although the Soviets report that it had an improved navigation system. *Salyut 7*, with *Cosmos 1686* (see below) still attached to it, reentered Earth's atmosphere in February 1991, raining debris on Argentina. Insufficient fuel was aboard to make a controlled reentry as the Soviets had done with all their previous space stations.

Salyut 7 hosted 10 crews and was resupplied by 13 Progress missions. During the *Salyut 7* era, a new record of 237 days was set by a three-man crew in 1984. Among the visiting crews to *Salyut 7* were a Frenchman, an Indian, and a Soviet woman, Svetlana Savitskaya, who made two flights, the first woman to do so. On the second flight, she also became the first woman to make a spacewalk.

Two modules, *Cosmos 1443* and *Cosmos 1686*, were docked with *Salyut 7*. *Cosmos 1443* was based on the *Cosmos 1267* design and the Soviets referred to it as a multipurpose vehicle that could be used as a cargo ship (with 2.5 times the capacity of Progress), space tug, and/or module to increase the habitable volume of the space station by 50 cubic meters. *Cosmos 1443* also had a descent module that returned 350 kilograms of material, including the results of 45 experiments, to Earth in 1983. Until early 1991, it was thought that *Cosmos 1686* was similar to *Cosmos 1443*, although a Soviet cosmonaut stated in 1985 that *Cosmos 1686* did not have a descent module. As the *Salyut 7/Cosmos 1686* complex approached the end of its life, however, the Soviets announced that *Cosmos 1686* did have a return capsule but that it had not been used. They reported that the entire module was of a different design than *Cosmos 1443* and its predecessors. As noted, the *Salyut 7/Cosmos 1686* combination reentered Earth's atmosphere in February 1991.

During the *Salyut 7* period, the Soviets had to overcome many difficulties with the space station itself, and nearly suffered another tragedy in 1983 when a launch vehicle about to send a crew into orbit caught fire. Using the emergency abort tower on top of the launch vehicle, the capsule containing the crew was propelled away from the launch pad and landed safely 3 kilometers away. The flight is referred to as Soyuz T-10A in the West. Both cosmonauts (V. Titov and Strekalov) have made spaceflights subsequently.

The hardware problems with the space station led the Soviets to begin using EVA routinely during the *Salyut 7* era. It was only in 1983 that a single crew performed two EVAs on one mission. Their purpose was to attach new solar panels to the main space station arrays to provide additional power and compensate for degradation of the original panels. Subsequent crews added more solar panels, one set of which were made of gallium arsenide, apparently the first time this substance had been used for space solar panels. The 1983 experience gave the Soviets confidence in repeated spacewalks by a single crew, and in 1984 a crew made six EVAs, five of which were needed to replace a fuel valve. The sixth was used to add more solar panels.

In 1985, the space station required another round of major repairs after it lost electrical power during a period that it was unoccupied. The station was essentially in a deep-freeze condition when the Soyuz T-13 repair crew arrived. Communications and radar systems were not functioning, complicating rendezvous and docking operations. The two-man crew reactivated the station and later became part of the first crew transfer. The three-man Soyuz T-14 crew was sent to *Salyut 7*, and for one week all five men shared the space station. Then, one member of the Soyuz T-13 crew and one from Soyuz T-14 returned to Earth, leaving one member of the Soyuz T-13 crew and two from Soyuz T-14 aboard. Crew transfers had been expected for years, since they are required for permanently occupied facilities (where crews normally rotate on a 5-6 month basis).

The Soyuz T-14 crew also represented another space first; it was the first known space mission aborted because of a medical emergency. The commander of the mission, Vladimir Vasyutin, developed an "inflammation" which could not be cured with medical supplies aboard the space station and the crew had to return in haste. The Soviets have not publicly provided further details about Vasyutin's affliction. The Soyuz T-15 crew, after first spending time on the new *Mir* space station in 1986 (see below), spent 50 days aboard *Salyut 7* closing out activities.

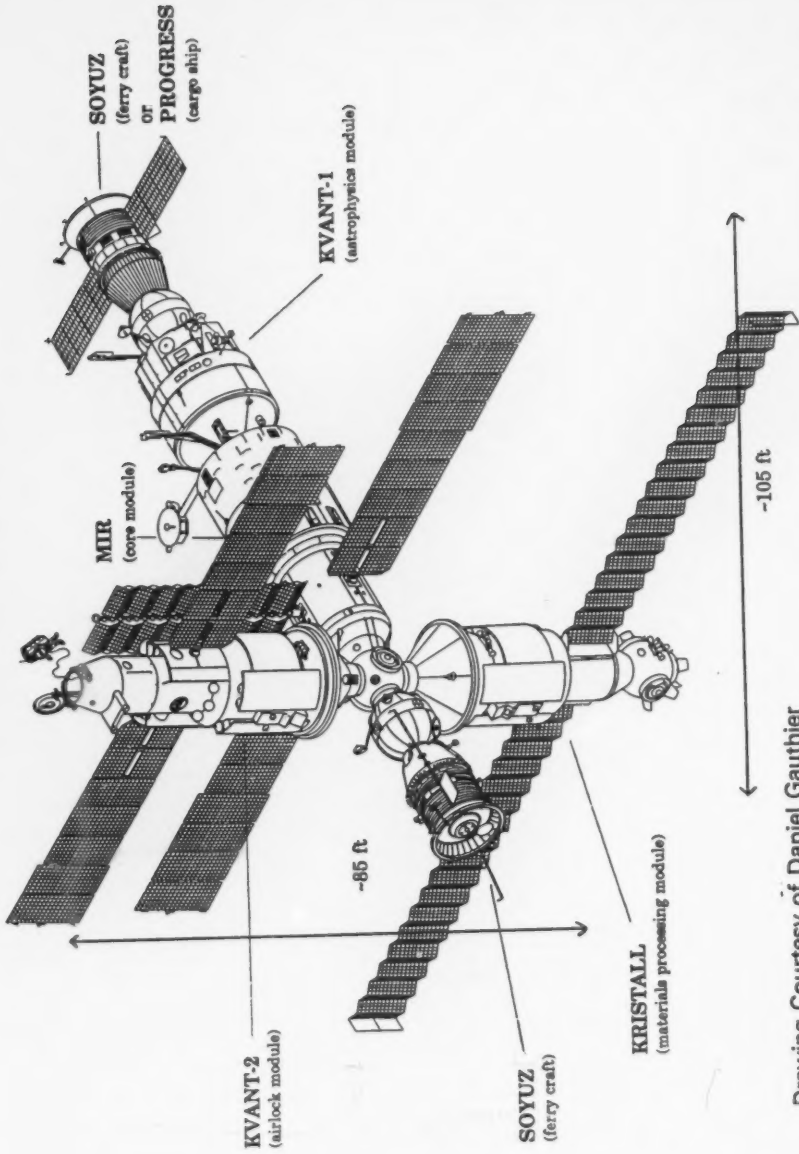
Third Generation: Mir ("Peace")

On February 20, 1986, the Soviets launched a third generation space station called *Mir*, the Russian word for peace. That the space station carries this name is not surprising since in 1985 the Soviets placed a proposal called "Star Peace" before the United Nations to counter President Reagan's "Star Wars" program. They have continued to open their space program, and created a "civilian" space agency called Glavcosmos (discussed in chapter 6) in 1985 to promote the image of a space program devoted to peaceful purposes. Calling their new space station *Mir*, rather than *Salyut 8*, was clearly part of this effort.

Mir is about the same size as the earlier Soviet space stations (they are all launched by the same vehicle), but has some significant differences. It has six docking ports rather than two, and most of the scientific equipment that normally is installed inside the space station is located instead on separate modules that dock at one of the ports, leaving a greater volume of space available in the station itself for the crew. This has enabled, for example, the provision of private sleeping quarters for two crew members, a modification made in response to complaints by previous crews about the lack of privacy. *Mir* has more and better computers to operate the station, relieving the crew of many routine tasks. Communications between *Mir* and ground control can be routed through a relay satellite, permitting greater communication times with the crews.

There are two axial docking ports (one at each end), and four side ports on a "collar" around the circumference of the forward end of the station. Modules

SOVIET SPACE STATION MIR COMPLEX



Drawing Courtesy of Daniel Gauthier

intended to dock permanently at one of the side ports dock first with the forward axial port and then are swung around using a type of remote manipulator system. The additional ports give the Soviets a flexible system, permitting several different research activities in specialized modules.

1986-1987. Only one crew, Soyuz T-15, docked with *Mir* in 1986; two Progress missions brought supplies. After spending 51 days on *Mir*, the crew used their Soyuz spacecraft to taxi over to *Salyut 7* where they spent another 50 days closing out activities. They also tested a flexible structure, extending it and then collapsing it again. The exercise is related to building large space structures in the future. They then taxied back to *Mir* and stayed for another 19 days.

A new crew was launched to *Mir* on February 5, 1987, and one of its two members, Yuriy Romanenko, went on to set a new duration record of 326 days. His companion, Aleksandr Laveikin, had to be replaced in the middle of the mission because of heart irregularities. A pre-scheduled visiting mission (that included a Syrian cosmonaut) was used to substitute Aleksandr Aleksandrov as Romanenko's crewmate. This personnel switch demonstrated the growing ability of the Soviet program to adapt to changing circumstances.

While Romanenko and Laveikin were aboard, they demonstrated one of the benefits of having a crew aboard a space station when they "rescued" the first module sent to *Mir*, an astronomical observatory called Kvant, which also carries gyroscopes for controlling the space station's orientation. The first attempt to dock Kvant with *Mir* failed because of a problem with Kvant's docking systems. The second attempt partially succeeded, but a hard docking could not be achieved. The crew performed a spacewalk to investigate the problem and discovered a foreign object in the docking port. They removed it and a hard dock was finally accomplished. The cosmonauts admitted when they returned to Earth that it had been a plastic toilet bag that had fallen into the docking adapter unnoticed when they were throwing trash into a Progress cargo vehicle docked with the station.

The crew also performed two more spacewalks to add a third main solar panel to *Mir*. Perhaps because of weight considerations, *Mir* was launched with only two of its three main arrays. Unlike the previous solar panel additions, which involved attaching more solar cells to existing arrays, this time the crew had to install the entire assembly, including connections into the space station.

As Romanenko's record-breaking mission came to an end in December 1987, the Soviets launched a new crew that took over *Mir* operations. In the 1985 crew transfer, the Soviets had left one of the original crew members on the space station with the new crew, but this time it was a complete crew replacement. At the end of 1987, *Mir* was occupied by Vladimir Titov and Musa Manarov. During 1987, there were seven Progress resupply missions.

1988-1990. Titov and Manarov were launched on December 21, 1987, with another cosmonaut, Anatoliy Levchenko, whom the Soviets stressed was an

experienced test pilot. He returned to earth with Romanenko and Aleksandrov after a week in orbit. His flight was interesting because the Soviets emphasized that it was related to their development of a reusable space shuttle. Immediately after landing, Levchenko was taken to an airfield where he piloted an aircraft, apparently to determine if a week in weightlessness affected his flying skills. (Levchenko died of a brain tumor in August 1988; the Soviets stress that his death was unrelated to his spaceflight.)

Titov and Manarov remained on *Mir* until December 21, 1988, for a new record of 366 days. During the year, they were visited by three crews, each composed of two Soviets and one international cosmonaut. The countries represented were Bulgaria in June, Afghanistan in August and France in November. Six Progress flights resupplied the station.

On the June flight, all three cosmonauts returned to Earth after a week in space, but one of the Soviet cosmonauts on the August flight, Polyakov, remained aboard *Mir* while his Soviet and Afghani colleagues returned. A physician, he monitored the health of Titov and Manarov during the end of their record-breaking flight, and remained on the space station after they left with two new crew-members who arrived in November. The two new space station occupants, Volkov and Krikalev, came with a Frenchman, Chretien, who stayed for three weeks, the longest space journey for any international cosmonaut. Chretien also was the first non-Soviet, non-American to make a spacewalk, and returned to Earth with Titov and Manarov in December.

The year was not trouble-free. A spacewalk in June to repair the Kvant astrophysical telescope was unsuccessful when the tool the cosmonauts were using broke; a second excursion was required four months later. On September 6, the Soviet/Afghani crew was returning to Earth when computer problems, exacerbated by pilot error, left them stranded in orbit for a day, after which they landed safely. When the next crew returned (Titov, Manarov and Chretien), they also encountered computer problems which delayed landing for three hours.

As 1989 began, the three cosmonauts on *Mir* were Volkov, Krikalev, and Polyakov. The Soviets announced that they would be replaced by a new crew in April, as the permanent occupancy of *Mir* continued. In April, however, the Soviets changed their mind and decided not to launch a new crew primarily because two modules intended to dock with *Mir* (Kvant-2 and Kristall, see below) still were not ready. Without the modules, there would have been little for the crew to do. Western reports that the decision was budget related seem to have little basis in fact, but the Soviets (now attempting to justify their program to the Soviet people) picked up on this approach and subsequently discussed how many rubles were saved because of the months *Mir* was vacant.

A new crew (Viktorenko and Serebrov) was launched in September 1989, with the expectation that Kvant 2, which has an airlock to make it easier for cosmonauts to leave the space station for spacewalks, would soon follow. There were additional technical delays with the module, however, and it was not

launched until November and docked in early December after overcoming docking problems.

During 1989, four Progress flights resupplied the space station, including two flights of a new version of the cargo craft, now designated Progress M. The new series uses the more advanced navigation computers used by the Soyuz TM spacecraft, and some have descent modules for returning material to Earth (previous Progress ships were not designed to survive reentry and each disintegrated in the atmosphere). The Soviets apparently have abandoned plans to use the Cosmos 1443 or Cosmos 1686 types of spacecraft for returning material to Earth. One of the Progress flights delivered a commercial protein crystal growth experiment developed by a U.S. company, Payload Systems Inc. The completed experiment returned to Earth with Viktorenko and Serebrov.

In 1990, *Mir* was occupied continuously, and was resupplied by four Progress cargo craft. One of these (Progress M-4) tested the new reentry capsule, and the next (Progress M-5) successfully returned material to Earth. Viktorenko and Serebrov remained on the station until February, and in January and February made five spacewalks, two of which tested a self-contained backpack similar to the U.S. "Manned Maneuvering Unit" flown on the space shuttle, to enable crews more freedom in operating in space (the backpacks contain all life support systems so the crew member does not have to be attached by an umbilical, as well as propulsion to maneuver near the spacecraft). A new crew (A. Solovyev and Balandin) took over in February, 1990. During launch, the thermal blankets covering their Soyuz TM-9 spacecraft partially detached from the vehicle necessitating two spacewalks by the crew so the blankets would not interfere with guidance sensors during reentry. The first spacewalk was especially difficult and took much longer than expected. When the cosmonauts returned to the Kvant-2 hatch to reenter the station, they discovered that it would not close (they had not properly depressurized the hatch when exiting the station, so it had swung out with such force that a hinge bent). They finally were able to get back into the lower half of Kvant-2 and close a hatch there. The spacewalk lasted 7 hours, longer than the time for which the spacesuits were designed. A crew later in the year (Manakov and Strekalov) attempted to fix the hatch and failed; another crew (Afanasyev and Manarov) in January 1991 finally succeeded.

Another module, *Kristall*, dedicated to materials processing research, was launched in June and, like its predecessors, encountered docking problems, but ultimately linked up with the station. *Kristall* is also equipped with a special docking adapter to which the Soviet *Buran* space shuttle can dock in the future.

The final crew to visit *Mir* in 1990 included the first commercial, paying cosmonaut--Toyohiro Akiyama, a journalist for Tokyo Broadcasting System (TBS) which paid the Soviets \$12 million for his flight. Akiyama was the first Japanese and the first journalist in space, and flew to *Mir* with cosmonauts Afanasyev and Manarov. He made daily broadcasts to his Japanese audience explaining his experiences in the space station, especially adjusting to weightlessness which he made clear was not altogether pleasant. Akiyama

returned to Earth with Manakov and Strekalov, who had been aboard since August, while Afanasyev and Manarov remained until May 1991. During their 175 days on Mir, they conducted four EVAs: one to fix the Kvant-2 hatch; two in preparation for moving solar panels from one part of the complex to another where they will not be in shadow so much of the time; and one to determine why the Progress M-7 cargo ship had been unable to dock (they discovered that the dish of the radar antenna at that port was missing).

Afanasyev and Manarov were replaced in May 1991 by Artsebarskiy and Krikalev, who were launched together with the first British astronaut, Helen Sharman, who also was a commercial cosmonaut. Like previous visitors, she returned to Earth after a week in space with the cosmonauts who had completed their mission.

The Soviets plan to launch two more modules to *Mir*, although the launch dates have slipped several times and continue to be uncertain. The Optizon or Spektr module is for atmospheric studies and the Priroda module will be used for remote sensing of the Earth. At one time, the Soviets announced plans to launch a module for medical research (Medilab) but those plans apparently have been canceled.

On all of their space stations, the Soviets have conducted a wide range of experiments in remote sensing, materials processing, and biology, as well as astronomical and atmospheric studies. They are detailed in the series of reports CRS prepares for the Senate (see *Introduction*).

U.S. Space Stations

Skylab

On May 14, 1973, the United States orbited a space station developed from a Saturn IV-B stage called *Skylab*. The space station suffered considerable damage when its micrometeoroid shield and one of the main solar panels were ripped off during launch, but ultimately three crews docked with *Skylab*, for 28, 59, and 84 days respectively. A wide range of experiments were conducted in solar observations, Earth resources observations, biomedical research, and materials processing. The last crew left the space station in February 1974, and in July 1979 the station reentered the Earth's atmosphere, raining debris over parts of Western Australia and the Indian Ocean.

The U.S./International Space Station "Freedom"

In his January 1984 State of the Union address, President Reagan called on NASA to build a permanently occupied space station within a decade. NASA is now embarked on a program with the European Space Agency, Japan and Canada to build such a station, but NASA estimates that it will not be available for initial operation until at least 1997 instead of 1994.

The space station, named *Freedom* in 1988, has gone through several design reviews. Originally, it was to have consisted of three different objects: an occupied base where astronauts would live and work; an automated platform nearby (a "co-orbiting" platform) for experiments that would be adversely affected by the presence of humans; and an automated platform circling the Earth's poles (a "polar" platform) for observations of the entire globe (the occupied base and co-orbiting platform would be in orbits that would not allow them to view the entire globe). NASA expected that there would be commonality in some of the systems (such as electrical power and communications) on the occupied base and two platforms.

In 1987, because of rising costs, NASA announced that the space station would be built in two phases: Phase 1 would include the polar platform and the occupied base, but with less of the lattice-work structure for the base that would be used for scientific experiments and other operations; and Phase 2, which would have included the co-orbiting platform and the rest of the lattice-work structure. (Phase 2 no longer exists since the program was again restructured in 1991.)

In 1989, NASA divorced the polar platform from the space station program because it became clear that there would be little if any technical commonality between the platform and the occupied base. NASA's Office of Space Science and Applications has taken over the polar platform, since its use is primarily for environmental observations (see section on Mission to Planet Earth in Chapter 3).

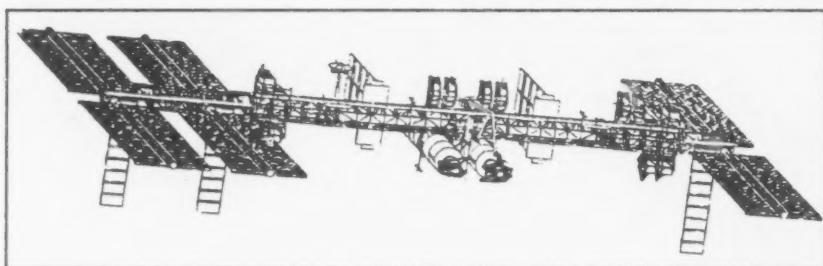
The space station thus became only the occupied base, consisting of one module for crew quarters (provided by the United States) and three laboratory modules, one each provided by the United States, the European Space Agency and Japan. The modules will be attached to a lattice-work truss structure, which will also accommodate solar panels (for producing electrical power--75 kilowatts according to the 1989 design) and other space station systems. Canada is building a Mobile Servicing System, and the United States planned to build a Flight Telerobotic Servicer, to facilitate work in the vicinity of the space station (such as servicing space station systems).

By 1990, the schedule called for "first element launch" at the end of 1995, initial operation in 1996, permanent occupancy in 1997, and "assembly complete" in 1999 (a delay of two years over the schedule as it existed in the summer of 1989). During the year, however, NASA discovered that the amount of maintenance that astronauts on spacewalks (extravehicular activity) would be required to perform was much higher than anticipated; the station weighed more than expected; and steadily increasing requirements for electricity to operate the station itself ("housekeeping functions") reduced the amount available for experiments. At the same time, Congress became increasingly concerned about space station costs and ordered NASA (in P.L. 101-507) to restructure the program to make it less costly on an annual basis and incremental, so that each phase would be discrete and independent of the next. Congress and other groups expressed other concerns about the space station,

especially its complete reliance on the space shuttle for construction and operations.

NASA completed the restructuring plan in March 1991. The "new" station will be shorter (106 meters instead of 148 meters), will have less power (56 kilowatts instead of 75 Kw), the two U.S. modules will be smaller (8 meters instead of 13 meters), and there will be fewer crew members (4 instead of 8). There will be substantially less assembly of the station in orbit, with as much as possible of the work performed on the ground prior to launch. Hence, the Flight Telerobotic Servicer has been eliminated from the program (its primary use was for assembly) and transferred to another part of NASA as a technology development program. The latest schedule calls for first element launch in 1996, initial operation (shuttle-tended) in 1997, and permanent occupancy in 1999, a two-year slip from the 1990 plan. There is no longer an "assembly complete" date, the new notion being that the space station will continually evolve during a "follow-on phase," not yet defined or budgeted. Eventually, NASA hopes the station will have the capability originally planned. The space station is still reliant on the space shuttle for assembly and initial operations at least.

SPACE STATION FREEDOM: MARCH 1991 DESIGN



By the end of 1990, NASA had estimated the cost for the U.S. portion of the program at \$38.3 billion through 1999 (the international partners are contributing hardware and systems valued at approximately \$8 billion). In the 1991 restructuring plan, NASA reduced the cost to \$30 billion, although the General Accounting Office (GAO) estimates it at \$40 billion. The space station is expected to be operational for 30 years. NASA does not have a cost estimate for the life of the program, but GAO estimates it at \$118 billion. These costs do not include the contributions of the international partners, who are expected to spend an additional \$8 billion through 1999.

Several outside groups, including the National Academy of Sciences, criticized the amount of science that will be able to be performed on the restructured space station, arguing it was not worth the investment. The White House has responded that science is not the only reason for building the space

station, that factors such as American leadership in space are just as or more important.

Continued debate over the cost of, purpose of and need for the space station has made this program extremely controversial, and the issues cannot be discussed here in sufficient depth; see CRS Issue Brief 85209, *Space Stations*, for more information.

Future Space Stations

While there is considerable discussion in the media and among aerospace professionals about the potential for space colonies, there are no firm plans for such an endeavor at this time. A popular scenario calls for construction of a 10,000 person colony at a Lagrange point where the gravitational forces of the Earth and Moon cancel each other out. This is often called the L-5 proposal, denoting one of the five Lagrange coordinates in the Earth-Moon system.

Broader proposals for future space stations were made in the 1986 report of the National Commission on Space (see part 1, chapter 7). The Commission recommended creation of a space infrastructure to support opening the inner solar system for science, exploration, and development over the next 50 years. In doing so, space stations (or spaceports as the Commission calls them) would be established in Earth, Moon and Mars orbits, and at the L1 Lagrange point. In addition, the Commission's "cycling spaceships" for transportation to Mars would be similar in design to the spaceports. All would have the ability to produce artificial gravity to compensate for the deleterious effects of weightlessness on the human body over long periods of time. The spaceports would be transfer points in the transportation system rather than colonies; the Commission felt that space colonies such as those proposed by the L-5 supporters were beyond the 50 year time frame of its report.

Long-term Soviet space station plans are not known with any certainty. A 1983 Pravda article discussed a complex of installations at altitudes ranging from 200 to 4,000 kilometers linked to Earth by freight and passenger transport spacecraft. The current debate in the Soviet Union over the wisdom of space spending may slow plans for expansive utilization of Earth orbit, however. The Soviets have mentioned development plans for "Mir-2" for launch in the mid-1990s, but recent reports from the Soviet Union suggest that such planning has been terminated. Since the existing *Mir* space station still is not fully utilized (only three of the five planned modules have been launched), there is no overwhelming need for a replacement station yet. One possibility raised by the Soviets is replacing the *Mir* core module only.

REUSABLE SPACE VEHICLES

The U.S. Space Shuttle

In 1972, President Nixon approved development of a reusable piloted spacecraft, called the space shuttle. The shuttle consists of a reusable orbiter about the size of a DC-9 which carries the crew and payloads, the external tank which holds the fuel for the three liquid hydrogen-liquid oxygen engines (called the main engines) for the orbiter, and two solid rocket boosters (SRBs) attached to either side to provide additional power during the first two and a half minutes of launch. The external tank breaks up in pieces as it reenters over the Indian Ocean; the SRBs are recovered from the Atlantic Ocean for refurbishment and reuse. Four flight-worthy orbiters were built: *Columbia*, *Challenger*, *Discovery*, and *Atlantis*. A fifth orbiter, *Enterprise*, was used for tests in the late 1970s, but was not designed to be flown in space. It is now on display by the Smithsonian Institution near Dulles Airport in Virginia. As discussed below, *Challenger* was destroyed in 1986. A replacement orbiter, *Endeavour*, has been built and is expected to make its first flight in 1992.

The Challenger Tragedy

After making 24 successful flights, the shuttle program suffered a tremendous tragedy when the 25th mission, STS 51-L, exploded 73 seconds after liftoff on January 28, 1986, at Cape Canaveral, Florida. The orbiter *Challenger* was destroyed and all seven crew members were killed--NASA astronauts Francis "Dick" Scobee, Michael Smith, Judith Resnik, Ronald McNair, and Ellison Onizuka and payload specialists Gregory Jarvis (an engineer with Hughes Aircraft Inc.) and S. Christa McAuliffe (a schoolteacher). The failure of a joint in one of the SRBs was blamed for the accident.

The investigation of the *Challenger* tragedy was performed by a commission established by President Reagan, called the Rogers Commission after its chairman, former Secretary of State William Rogers. Although the Commission did not affix blame to any individuals, the public record made clear that employees at NASA and Morton Thiokol, which manufactures the SRBs, should have chosen not to launch that day. The weather was unusually cold at Cape Canaveral and temperatures had dipped below freezing during the night. Test data had suggested that the seals (called O rings) around the SRB joints lost much of their effectiveness in very cold weather. A Thiokol engineer at the launch site had recommended against launch, but was overruled by his superiors at the company's Utah headquarters. NASA's Marshall Space Flight Center was responsible for the SRB program within the agency, and officials there approved the launch as well.

Pre-Challenger Shuttle Missions

The aftermath of the *Challenger* tragedy called into question NASA management practices, past decisions about the design of the SRBs, and the health of the U.S. civilian space program. To a large extent, the tragedy

overshadowed the successes that the shuttle program enjoyed prior to January 28, 1986.

The first space shuttle flight was successfully accomplished on April 12, 1981, and was followed by three more orbital test flights (one in 1981, two in 1982). The first "operational" launch of the shuttle took place on November 11, 1982, and was used to send two communications satellites into geostationary orbit.

Four shuttle missions were launched in 1983, including missions that included the first U.S. woman in space (Sally Ride) and the first black American (Guion Bluford), and the first flight of the European-built Spacelab, which flies in the cargo bay of the orbiter. The Spacelab 1 mission included the first non-American to fly on an American piloted mission (a West German). Five shuttle missions were successfully accomplished in 1984, and included the first use of the Manned Maneuvering Unit which allows an astronaut to travel away from the shuttle without being tethered to it. On later flights that year, three satellites were retrieved by astronauts, one of which (the Solar Maximum Mission) was repaired and redeployed in orbit, while the other two (Westar and Palapa) were returned to Earth for repair and eventual relaunch. Kathryn Sullivan became the first American woman to perform a spacewalk, Sally Ride became the first American woman to fly into space twice, and procedures for in-space refueling were demonstrated.

In 1985, nine shuttle flights were successfully accomplished, including the first dedicated mission for DOD. This mission garnered considerable attention from the media, which was unaccustomed to the lack of information about launch schedules and payloads involved in a DOD launch. The media portrayed this an example of the "militarization" of NASA, but it may be viewed as a continuation of past policy as all U.S. launch vehicles are used by both military and civilian customers.

During 1985, shuttle crew size increased to eight, and one of the crews included U.S. Senator Jake Garn. The utility of the shuttle for repairing satellites was demonstrated again with the repair of the Leasat communications satellites which had failed to function after deployment on an earlier shuttle flight. Two Spacelab missions were flown, including one with animals, the first time humans and animals have flown together in space. Another crew tested space construction techniques. One of the 1985 missions encountered the first serious problem during launch when one of the three main engines ceased functioning during ascent. The crew safely reached orbit, although it was not at the altitude intended.

There was one successful shuttle launch in January 1986 which included U.S. Congressman Bill Nelson among the crew. The next flight was the ill-fated STS 51-L.

Return to Flight

On September 29, 1988, the space shuttle made its first flight since the *Challenger* disaster. The mission, using the orbiter *Discovery*, deployed a Tracking and Data Relay Satellite identical to the one lost aboard *Challenger*. The five crew members--Frederick (Rick) Hauck, Richard Covey, John (Mike) Lounge, David Hilmer, and George (Pinky) Nelson--remained in orbit for four days. A second shuttle flight, dedicated to DOD requirements, was launched in December.

During 1989, NASA conducted five shuttle launches, slowly increasing the flight rate to a planned 10 missions per year. The five missions all carried spacecraft into orbit: the Magellan mission to Venus, and the Galileo mission to Jupiter (both discussed in Chapter 4); another Tracking and Data Relay Satellite; and two Department of Defense satellites.

In 1990, NASA accomplished six shuttle flights, five of which deployed spacecraft--the Hubble Space Telescope, the Ulysses probe that will travel to the Sun, a communications satellite (this mission also retrieved NASA's Long Duration Exposure Facility), and two DOD satellites--while the sixth was a Spacelab mission for astronomy called ASTRO-1. The launch rate was less than planned because of hydrogen leaks discovered in two of the three orbiters. All shuttle flights were suspended for five months while NASA determined the nature of and remedied the problem (see CRS Issue Brief 90114, *NASA Under Scrutiny: Shuttle and Hubble* for further information).

In the future, the shuttle will be used less for carrying satellites to orbit that could as easily be launched by "expendable launch vehicles" or ELVs (rockets), such as communications and DOD satellites. The shuttle's primary use will be for missions that specifically require human presence, such as Spacelab missions for life science, materials processing or earth observation research, or for construction and operation of the space station.

National Aerospace Plane (NASP)

For the longer term future, the United States is conducting research and development on several new propulsion technologies and materials through the National Aero-Space Plane (NASP) program. The concept is not new, but it is believed that the technologies are finally becoming available to achieve a marriage between air-breathing and rocket engine technologies. Ultimately, NASP could lead to a replacement for the space shuttle and other launch vehicles for taking people and some cargo into orbit. It could also lead to the development of a commercial aircraft capable of taking people around the world in a few hours. It is in this application that President Reagan referred to it as the "Orient Express" in his 1986 State of the Union address.

The NASP program is funded through the Air Force and NASA. The near-term goal of the program is to develop an "X" plane (in the mold of the X-1 or X-15) to test whatever materials and technologies have been developed through

the research program at that time. Aerospace plane technologies are so advanced that it is not known yet whether or not they will lead to operational vehicles, much less what such vehicles will cost. The NASP program was very controversial in 1989, and led to a National Space Council review of the program. The Space Council recommended that the program be slipped by two and a half years, and that it continue to be funded jointly by DOD and NASA (DOD had wanted to terminate its involvement). NASP is discussed in more detail in CRS Issue Brief 89128, *National Aero-Space Plane*.

Soviet Space Shuttle "Buran"

After years of Western speculation, the Soviets finally admitted in 1987 that they were, in fact, developing a space shuttle of their own. On November 15, 1988, the first (and so far only) flight of the Soviet shuttle took place in a completely automated mode--no crew was aboard. The shuttle, called *Buran*, made two orbits of the Earth and then landed on a runway at Tyuratam 12 kilometers from the pad from where it had been launched. The launch took place two weeks after an earlier attempt was terminated 51 seconds before liftoff when a computer determined that a launch service tower had not retracted sufficiently.

The Soviet shuttle physically resembles the U.S. shuttle, prompting some Western observers to charge that it is a "carbon copy" of the American version. This is an exaggeration, however. The Soviet shuttle is different in concept from the U.S. shuttle. Each time the U.S. shuttle is launched, all four pieces (the airplane-like orbiter, the two side-mounted Solid Rocket Boosters, and the large cylindrical External Tank) must be used. The main engines for achieving orbit are on the orbiter; the External Tank simply holds the fuel for them. Thus, whatever is being carried into space is limited to a size and weight that can fit inside the orbiter's cargo bay. The Soviets built a more versatile system in that the main engines are on the Energiya launch vehicle (see part 1, chapter 6) itself. The orbiter exists independently so that if they have something too large or too heavy to fit inside their orbiter's cargo bay, they can simply leave the orbiter off and the cargo can be placed in a canister and attached directly to Energiya. Thus the Soviets have a launch vehicle (Energiya) that can be used to place anything in space up to 100 tons in mass--the orbiter is only one payload it can carry.

Initial Western reports that the Soviet shuttle is equipped with air-breathing engines to provide an ability to attempt a second landing if necessary proved inaccurate. The Soviets have stated that their shuttle must land on the first attempt (like its U.S. counterpart), and that they are building two contingency landing sites, one in the Western Soviet Union and one in the eastern part of the country. For now, the landing strip at Tyuratam is apparently the only one.

The launch date for the next *Buran* mission has slipped several times, from 1989 to 1992. As currently planned, the 1992 mission (also without a crew) is

expected to dock with the *Mir* space station. The first flight with a crew apparently is not planned until 1995 (a three year slip).

Following *Buran*'s first flight, the Soviets stated that after the test phase was completed, they would launch their shuttle only once a year. There are conflicting statements on how many shuttles will be built (there are two flightworthy shuttles today), but all apparently will be named *Buran* (unlike the U.S. program where each orbiter has its own name). Where *Buran* fits into the overall Soviet space program continues to be unclear, both in the West and apparently in the Soviet Union as well. Soviet space officials have offered lists of missions for *Buran* to accomplish, but all seem far in the future (construction of solar power stations, for example). The delay in the next *Buran* flight may be partially attributable to technical difficulties, but probably is more related to lack of support for the program at a time of increased budget constraints in the Soviet space program. In 1989, the Soviets stated that the *Energiya/Buran* program consumed \$2 billion of their \$11 billion/year space budget. The future of the *Buran* program is much in doubt at the present time.

TABLE 3a.
Summary List of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1961						
Apr. 12	Vostok 1	Gagarin	4,725	1:48	same	1:48
May 6	MR-3	A. Shepard	1,290	:15	same	:15
July 21	MR-4	Grierson	1,266	:16	same	:31
Aug. 6	Vostok 2	G. Titov	4,731	25:18	same	27:06
1962						
Feb. 20	MA-6	Glenn	1,355	4:55	same	5:26
May 24	MA-7	Carpenter	1,349	4:56	same	10:22
Aug. 11	Vostok 3	Nikolayev	4,722	94:22	same	121:28
Aug. 12	Vostok 4	Popovich	4,728	70:57	same	192:25
Oct. 3	MA-8	Schirra	1,373	9:13	same	19:35
1963						
May 15	MA-9	Cooper	1,376	34:20	same	53:55
June 14	Vostok 5	Bykovskiy	4,720	119:06	same	311:31
June 16	Vostok 6	Terezhkova	4,713	70:50	same	382:21
1964						
Oct. 12	Voskhod 1	Komarov Yegorov Feoktistov	5,320	24:17	same	455:12

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1965						
Mar. 18	Voskhod 2	Bel'yayev Leonov Grisom (2)	5,882	28:02	same	507:16
Mar. 23	Gemini 3	Young McDivitt	3,225	4:53	same	63:41
June 3	Gemini 4	White Cooper (2)	3,574	97:56	same	259:33
Aug. 21	Gemini 5	Conrad Borman	3,605	190:55	same	641:23
Dec. 4	Gemini 7	Lovell Schirra (2)	3,663	330:35	same	1302:33
Dec. 15	Gemini 6	Stafford	3,546	25:51	same	1354:15
1966						
Mar. 16	Gemini 8	Armstrong Scott	3,788	10:41	same	1376:37
June 3	Gemini 9	Stafford (2)	3,750	72:21	same	1520:19
July 18	Gemini 10	Gernan Young (2)	3,741	70:47	same	1661:53
Sept. 12	Gemini 11	Collins Conrad (2)	3,860	71:17	same	1804:27
Nov. 11	Gemini 12	Gordon Lovell (2) Aldrin	3,763	94:35	same	1993:37
1967						
Jan. 27	AS-204	Grisom (3)+ White (2)+ Chaffee+	20,412	[Not a space flight, but date of fatal fire on pad during pre-flight test.]		
Apr. 23	Soyuz 1	Komarov (2)+	6,450	26:48	same	534:04

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1968						
Oct. 11	Apollo 7	Schirra (3) Eisele Cunningham	20,569	260:09	same	2774:04
Oct. 26	Soyuz 3	Beregovoy	6,575	94:51	same	628:55
Dec. 21	Apollo 8	Borman (2) Lovell (3) Andera	43,663	147:01	same	3215:07
1969						
Jan. 14	Soyuz 4*	Shatalov Yeliseyev Khrunov	6,625	71:21	71:21 47:49 47:49	795:54
Jan. 15	Soyuz 6*	Volynov	6,585	72:54	72:54	868:48
Mar. 3	Apollo 9	McDivitt (2) Scott (2) Schweickart	43,185	241:01	same	3938:10
May 18	Apollo 10	Stafford (3) Young (3) Cernan (2)	48,638	192:03	same	4514:19
July 16	Apollo 11	Armstrong (2) Collins (2) Aldrin (2)	49,698	195:19	same	5100:16
Oct. 11	Soyuz 6	Shonin Kubasov	6,577	118:43	same	1106:14
Oct. 12	Soyuz 7	Filipchenko Gorbatko V. Volkov	6,570	118:40	same	1462:14
Oct. 13	Soyuz 8	Shatalov (2) Yeliseyev (2)	6,646	118:51	same	1699:56
Nov. 14	Apollo 12	Conrad (3) Gordon (2) Bean	49,804	244:36	same	5834:04

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1970						
Apr. 11	Apollo 13	Lovell (4) Haise Swigert	49,960	142:55	same	6392:49
June 1	Soyuz 9	Nikolayev (2) Serafin Yuzov	6,500	424:59	same	2549:54
1971						
Jan. 31	Apollo 14	A. Shepard (2) Rosen Mitchell (Occupied by Soyuz 11 crew)	46,347	216:02	same	6910:55
Apr. 10	Salyut 1	Shatalov (3)	18,600	47:46	same	2993:12
Apr. 22	Soyuz 10	Yeliseyev (3)	6,575			
June 6	Soyuz 11	Rukavishnikov Debravitskiy + V. Volkov (2) + Palamarev	6,575	570:22	same	4404:18
July 26	Apollo 15	Scott (3) Ireton Worden	52,759	295:12	same	7798:31
1972						
Apr. 16	Apollo 16	Young (4) Mattingly Duke	51,571	295:51	same	8524:34
Dec. 7	Apollo 17	Cernan (3) Schmitt Evans	51,808	301:52	same	9499:40

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (N)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1973						
May 14	Soyuz 1	(Occupied by Soyuz 2, 3 & 4 crews)	89,439		same	11518:10
May 25	Soyuz 2	Conrad (4) Kerwin	30,803	672:50	same	15790:37
July 28	Soyuz 3	Weitz Bean (2) Garrison Lousma	30,894	1427:09	same	4488:50
Sept. 27	Soyuz 12	Lousma Mikharov	8,575	47:16	same	21851:25
Nov. 18	Soyuz 4	Carr E. Gibson	31,222	2017:16	same	4878:42
Dec. 18	Soyuz 13	Pogue Klimuk Lebedev	8,575	188:56	same	
1974						
June 24	Soyuz 3	(Occupied by Soyuz 14 crew)	18,900	377:30	same	5631:42
July 3	Soyuz 14	Popovich (2) Aryabhin Serafinov	8,570	48:12	same	8728:06
Aug. 26	Soyuz 15	Demin Filipchenko (2)	8,570	142:24	same	8012:54
Dec. 2	Soyuz 16	Rukavishnikov (2)	8,570			
Dec. 26	Soyuz 4	(Occupied by Soyuz 17, 18 crews)	18,900			

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR. MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR. MIN)		
1975						
Jan. 10	Soyuz 17	Gubarev Grebko	6,570	709:20	same	7431:34
Apr. 5	Anomaly (Soyuz 16A)	Lezavre (2)	6,570	:20	same	7432:14
May 24	Soyuz 18	Mikarev (2)	6,570	151:20	same	10454:54
July 15	Soyuz 19	Sennat'yarov (2)	6,600	142:31	same	10739:56
July 15	ASTP	Leonov (2) Kulbasov (2) Stafford (4) Slayton Brand	14,743	217:28	same	22503:49
1976						
June 22	Salyut 5	(Occupied by Soyuz 21, 24 crews)	18,900			
July 6	Soyuz 21	Volynov (2)	6,570	1182:23	same	13104:42
Sept. 15	Soyuz 22	Zholobov Bykovskiy (2)	6,570	189:52	same	13484:26
Oct. 14	Soyuz 23	Alksanov Zudov Korobovskiy	6,570	48:07	same	13580:40
1977						
Feb. 7	Soyuz 24	Gorbalko (2)	6,570	425:26	same	14431:32
Sept. 29	Salyut 6	Glaikori (Occupied by Soyuz 26, 27, 28, 29, 30, 31, 32, 35, 36, 37, 38, 39, 40, 41, 42, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95, 96, 97, 98, 99, 100)	18,900			
Oct. 9	Soyuz 25	Korolenko Ryumin	6,570	48:45	same	14592:02
Dec. 10	Soyuz 26	Romanenko Grebko (2)	6,570	898:06	2314:00	19157:02

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1978						
Jan. 10	Soyuz 27	Dzhanibekov Makarov (3)	6,570	1558:53	142:56	19443:00
Mar. 2	Soyuz 28	Gubarev (2) Rennak (Czechoslovakia)	6,570	190:16	same	19823:32
June 15	Soyuz 29	Kovalenko (2) Ivanchenkov Klimuk (3)	6,570	1911:23	3350:48	26525:08
June 27	Soyuz 30	Hermaszewski (Poland)	6,570	190:03	same	26905:14
Aug. 26	Soyuz 31	Dykovskiy (3) Jahn (German Dem. Rep.)	6,570	1828:14	188:40	27282:52
1979						
Feb. 25	Soyuz 32	Lyakhov Byumin (2) (Returned unoccupied)	6,570	2556:24	4200:36	35684:04
Apr. 10	Soyuz 33	Bukharishnikov (3) Fedorov (Bulgaria)	6,570	47:01	same	35778:06
June 6	Soyuz 34	(Launched unoccupied, returned Soyuz 32 crew)	6,570	1770:17		

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR-MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR-MIN)		
1980						
Apr. 9	Soyuz 35	Popov Bryunin (3)	6,570	1321:29	4438:12	44650:30
May 28	Soyuz 36	Kobasov (3) Farkas (Hungary)	6,570	1550:54	188:46	45028:02
June 5	Soyuz T-2	Malyshev Alksenov (2)	7,000	94:19	same	45216:40
July 23	Soyuz 37	Gorbalko (3) Pham Tuan (Vietnam)	6,570	1911:17	188:42	45594:04
Sept. 18	Soyuz 38	Romanenko (2) Tamayo Mendez (Cuba)	6,570	188:43	same	45971:30
Nov. 27	Soyuz T-3	Kizim Makarov (4) Serebriy	7,000	307:08	same	46892:54
1981						
Mar. 12	Soyuz T-4	Kovalenok (3) Savinykh Dzhanibekov (2)	7,000	1794:38	same	50482:10
Mar. 22	Soyuz 39	Gurragcha (Mongolia)	6,570	188:43	same	50869:36
Apr. 12	STS-1	Young (5) Crippen	94,658	54:21	same	22812:31
May 14	Soyuz 40	Popov (2) Frunzetu (Romania)	6,570	188:41	same	51236:58
Nov. 12	STS-2	Engle Truzy	103,811	54:13	same	22720:57

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR-MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR-MIN)		
1962						
Mar. 22	STS-3	Louma (2) Fullerton (Occupied by Soyuz T-5, T-6, T-7, T-9, T-10, T-11, T-12, T-13, T-14 and T-15 crews)	106,000	192:05	same	23105:07
Apr. 19	Salyut 7		18,900			
May 13	Soyuz T-5	Berezovoy	7,000	2549:06	5073:05	81383:06
June 24	Soyuz T-6	Lebedev (2) Dzhanibekov (3) Ivanchenkov (2) Chretien (France)	7,000	189:51	same	61982:41
June 27	STS-4	Matingly (2) Hartsfield	108,797	169:11	same	23443:29
Aug. 19	Soyuz T-7	Popov (3) Serebrov Savitskaya Brand (2) Overmyer J. Allen Lenoir	7,000	2712:51	189:52	62822:17
Nov. 11	STS-5		111,201	122:14	same	23933:25
1963						
Apr. 4	STS-6	Weitz (2) Bobko Musgrave Peterson V. Titov	114,201	120:24	same	24414:01
Apr. 20	Soyuz T-8	Strekalov (2) Serebrov (2) Crippen (2) Hauk Ride Fabian	7,000	48:18	same	62867:11
June 18	STS-7		110,013	146:24	same	25146:01
June 27	Soyuz T-9	Thagard Lyakhov (2) A. Aleksandrov	7,000	3585:46	same	69539:43

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1963 (cont.)						
Aug.	STS-8	Truly (2) Brandenstein Thornton Bluford D. Gardner	104,675	145:09	same	25871.46
Sept.	(Soyuz T-10A)	V. Titov Strekalov	(Not a spaceflight. Crew jettisoned using emergency abort system after fire erupted in launch vehicle prior to launch)			
Nov.	STS-9	Young (6) Shaw Parker Garriott (2) Lichtenberg Merbold (W. Germany)	110,031	247:47	same	27364.23
1964						
Feb.	STS 41-B	Brand (3) R. Gibson McCandless McNair Stewart Kizim (2) V. Solovyev Atkov	113,508	191:16	same	28314.48
Feb.	Soyuz T-10	Malyshov (2) Strekalov (3) Sharma (India)	7,000	1510:43	5686:50	86899.13
Apr.	Soyuz T-11	Crippen (3) Scofield Hart van Hoften G. Nelson	7,000	4385:48	189:41	87468.16
Apr.	STS 41-C		115,342	167:40	same	29153.08

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1964 (cont.)						
July	17 Soyuz T-12	Dzhanibekov (4) Savitskaya (2) Volk	7,000	283:14	same	68317.58
Aug.	30 STS 41-D	Hartsfield (2) Coats Resnik Hawley Mullane C. Walker	119,491	144:57	same	30022.50
Oct.	5 STS 41-G	Crippen (4) McBride Ride (2) Sullivan Leestma Scully-Power Garneau (Canada) Hauck (2) D. Walker J. Allen (2) A. Fisher D. Gardner (2)	110,119	197:24	same	31404.38
Nov.	8 STS 51-A		119,421	191:45	same	32363.23

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1965						
Jan. 24	STS 51-C	Mattingly (3) Shriver Onizuka Buchi Payton Bobko (2) D. Williams Hoffman Griggs Seddon C. Walker (2) Gurn Overmyer (2) Gregory Thornton (2) Thagard (2) Lind van den Berg Wang Dzhanibekov (5) Savinykh (2) Brandenstein (2) Creighton Lucid Nagel Fabian (2) Baudry (France) Sultan Salman Al- Saad (S. Arabia) Fullerton (2) Bridges Henize England Muangrave Bartoe Aron	N/A	73:33	same	32731:06
Apr. 12	STS 51-D		113,802	167:55	same	33906:33
Apr. 29	STS 51-B		111,982	168:09	same	35083:36
June 6	Soyuz T-13		7,000	2091:12	2091:12	96045:01
June 17	STS 51-G		116,310	169:39	4035:51 same	36271:09
July 29	STS 51-F		114,590	190:45	same	37606:24

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1965 (cont.)						
Aug. 27	STS 61-I	Engle (2) Covey Lounge W. Fisher van Hoften (2) Vasyutin Grechko (3) A. Volkov Bobko (3) Grabe Hilmers Stewart (2) Pailes Hartsfield (3) Nagel Buchli (2) Bluford (2) Dunbar Ockels (ESA) Furrer (FRG) Messerschmid (FRG) Shaw (2) O'Connor Spring Cleave Rosa C. Walker (3) Neri (Mexico)	118,961	170:18	same	38457:54
Sept. 17	Soyuz T-14		7,000	1557:52	1557:52 213:13 1557:52 same	96373:58
Oct. 3	STS 61-J		N/A	97:47	same	38946:49
Oct. 30	STS 61-A		110,568	168:44	same	40296:41
Nov. 26	STS 61-B		118,064	165:05	same	41452:16

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1988						
Jan. 13	STS 61-C	R. Gibson (2) Bolder Hawley (2) G. Nelson (2) Chang-Diaz Cenker B. Nelson	116,210	146:04	same	42474.44
Jan. 28	STS 61-L	Scobee (2) + Smith + Resnik (2) + Onizuka (2) + McNair + Jarvis + McAuliffe + (Occupied by Soyuz T-15, TM2, TM3, TM4, TM5, TM6, TM7, TM8, TM9, TM10 and TM11 crews) Kizim (3) V. Solovyev (2)	121,939	Exploded 73 seconds after liftoff. All aboard were killed.		
Feb. 20	Mir					
Mar. 13	Soyuz T-15		7,000	3000:01	same	104374.00
1987						
Feb. 5	Soyuz TM-2	Romanenko (3) Levitkin	7,070	4179:26	7835:38 4179:26	116389.04
July 22	Soyuz TM-3	Viktorenko A. Aleksandrov (2) Faria (Syria) V. Titov (2) Manarov	7,070	3847:17	191:06 3847:17	120618.31
Dec. 21	Soyuz TM-4	Levchenko	7,070	4320:55	191:06 8782:39 8782:39 169:56	138373.47

Table 3a. (continued)
Summary of Piloted Space Flights

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1968						
June 7	Soyuz TM-5	Savinykh (3) A. Solov'yev A. Alexandrov (Bulgaria)	7,070	2193:47	236:10	139062:17
Aug. 29	Soyuz TM-6	Lyakhov (3) Polyakov Mohmand (Afghanistan)	7,070	2741:34	212:27 5782:36 212:27	145289:47
Sept. 29	STS-28	Hauck (3) Covey (2) Lounge (2) Hilmers (2) G. Nelson (2) A. Volkov (2) Krikalev Chretien (2) (France) R. Gibson (3) G. Gardner Mullane (2) Ross (2) W. Shepard	102,325	97:00	same	42969:44
Nov. 26	Soyuz TM-7		7070	3635:09	3635:09 3635:09 594:07	153164:12
Dec. 2	STS-27		N/A	105:06	same	43486:14
1969						
Mar. 13	STS-29	Costa (2) Blaha Buchli (3) Springer Bagan D. Walker (2) Grabe (2) Thagard (3) Cleave (2) Lee	83,874	119:39	same	44083:29
May 4	STS-30		101,119	96:57	same	44568:14

Table 3a. (continued)
Summary of Piloted Space Flights

Summary of 11 Space Operations - 1968-1990

Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1968 (cont.)						
Aug.	8 STS-25	Shaw (3) Richards Leestma (2) Adamsen M. Brown Viktorenko (2) Serebrov (3) D. Williams (2) McCulley Lucid (2) Baker Chang-Diaz (2) Gregory (2) Blaha (2) Carlier Muagrove (3) K. Thornton	N/A	121:01	same	46173:19
Sept.	5 Soyuz TM-6		7,070	3990:56	same	161136:08
Oct.	18 STS-34		107,062	119:39	same	45771:34
Nov.	22 STS-33		N/A	120:08	same	46372:14
1990						
Jan.	9 STS-32	Brandenstein (3) Webster Dunbar (2) Ivins Low	255,994	261:02	same	47677:34
Feb.	11 Soyuz TM-9	A. Solov'yev (2) Balandin Creighton (2) Casper Hilmer (3) Thorst Mullane (3)	7,070	4297:19	same	169730:46
Feb.	28 STS-36		N/A	106:19	same	48208:59

Table 3a. (continued)
Summary of Piloted Space Flights

Summary of Piloted Space Flights						
Launch Date	Vehicle Name	Crew (No. of Flights)	Ship		Crew Duration (HR:MIN)	National Cumulative Person-hours
			Weight (KGS)	Duration (HR:MIN)		
1990 (cont.)						
Apr. 24	STS-31	Shriver (2) Balden (2) Hawley (3) McCandless (2) Sullivan (2) Manakov	249,115	121:15	same	48815:14
Aug. 1	Soyuz TM-10	Steklov (4) Richards (2) Cabana W. Shepard (2) Akera Melnick Covey (3) Culbertson Meade Springer (2) Genar	7,070	3140:36	same	176011:58
Oct. 6	STS-41		259,593	98:11	same	49306:09
Nov. 15	STS-38		N/A	117:55	same	49895:44
Dec. 2	STS-35	Brand (4) Gardner (2) Lounge (3) Hoffman (2) Parker (2) Parise Durrance Manasev Manarov (2) Akiyama (Japan)	256,385	215:05	same	51401:19
Dec. 2	Soyuz TM-11		7,070	in orbit	in orbit in orbit 189:55	177625:77**

* Soyuz 4 was launched carrying only Shatalov. Soyuz 6 carried Volynov, Yeliseyev and Khronov. The latter two transferred to Soyuz 4 via a spacewalk and returned to Earth with Shatalov. Beginning in 1985, the Soviets began routinely sending crews up on one ship and returning them on another as part of space station operations.

** Includes Manasev's and Manarov's time through Dec. 31, 1990; they are still in orbit (Akiyama returned with the Soyuz TM-10 crew in Dec. 1990.)

+ Fatality. Four Soviets died in spaceflights: Komarov on Soyuz 1 (1967) when the parachute lines tangled during descent; and the Soyuz 11 crew (1971) when an improperly closed vent allowed the cabin atmosphere to vent into space and the three men (who were not wearing spacesuits) asphyxiated. Seven Americans died in the 1986 space shuttle Challenger tragedy when it exploded 73 seconds after launch; three astronauts died in the 1987 Apollo 204 fire.

Prepared by CRS.

TABLE 3b. Number of Individuals Who
Have Flown in Space

COUNTRY	TOTAL INDIVIDUALS WHO HAVE FLOWN IN SPACE
United States	148
Soviet Union	70
Afghanistan*	1
Bulgaria*	2
Canada+	1
Czechoslovakia*	1
Cuba*	1
France*+	2
German Democratic Republic*	1
Germany, Federal Republic of+	3
Hungary*	1
India*	1
Japan*	1
Mexico+	1
Mongolia*	1
Netherlands+	1
Poland*	1
Romania*	1
Saudi Arabia+	1
Syria*	1
Vietnam*	1
TOTAL	241

(+ Indicates individual flew on U.S. mission; * indicates individual flew on Soviet mission.) Prepared by CRS.

CHAPTER 3

SPACE APPLICATIONS FLIGHTS

Applications satellites are those spacecraft whose functions provide direct applications to a user community, including communications, navigation, remote sensing of the Earth's surface, weather, and geodesy. While the term is usually applied to civilian satellites, they are close cousins of military satellites, and in most cases it is extremely difficult to distinguish whether a particular satellite should be counted as military or civilian. Military space activities in general are discussed in chapter 5.

COMMUNICATIONS

The United States was the first country to experiment with communications satellites. At first, satellites which could store information for later relay to Earth (called store/dump) were used and, at about the same time, passive balloon reflectors (Echo, for example). Beginning in 1963, the United States started placing communications satellites in geostationary orbit at 35,880 kilometers altitude above the Equator (a satellite in this orbit will maintain a fixed position relative to a given point on the ground). This type of communications satellite receives signals transmitted from a ground station, boosts the power of the signals and instantly retransmits them to another ground station (or sometimes multiple ground stations) hundreds or thousands of kilometers away. Only three properly positioned geostationary satellites are needed to provide global communication.

Communications satellites are used today to send television signals, telephone calls and data around the world. Costs for using satellites have diminished as capacity has grown. Commercial and Government satellites are regularly launched to serve the military, civilian and commercial sectors. NASA has also established the Tracking and Data Relay Satellite System (TDRSS) for relaying communications between spacecraft and ground controllers.

NASA is building the Advanced Communications Technology Satellite (ACTS) to demonstrate new technologies for communications satellites generally. The program was controversial for years because the Reagan Administration believed that the private sector should fund this research, while Congress consistently supported the view that such activities are too expensive for the private sector to pursue alone, and that in order to maintain U.S. competitiveness in these technologies, Government support is needed. The private sector is paying for part of the ACTS program, but the majority of the funding is from NASA. ACTS is scheduled for launch in 1992.

The United States initiated creation of the International Telecommunication Satellite Organization (INTELSAT), established in 1964 to provide for an international communication satellite system. Today, 120 countries belong to INTELSAT. The success of INTELSAT spawned creation of the International Maritime Satellite Organization (INMARSAT) in 1979 for maritime communications and it now has 64 members. The Soviet Union does not belong to INTELSAT (although it uses the system, and is expected to become a member sometime in 1991), but is a member of INMARSAT.

The Soviets established the first domestic communications satellite system (as opposed to an international system like INTELSAT) beginning in 1965. The Soviets used a different approach to communications satellites, deploying their Molniya satellites in highly elliptical orbits with an apogee of approximately 40,000 kilometers over the northern hemisphere and a perigee of approximately 500 kilometers over the southern hemisphere, rather than in geostationary orbit. This provides a long linger time over the northern hemisphere (8 hours), and four of these satellites can provide 24 hour coverage within the Soviet Union. The Molniya type of orbit is better than geostationary orbit for communicating at high latitudes where the curvature of the Earth makes it difficult for signals to reach from the Equator.

Although the Molniya orbit is good for internal communications in the Soviet Union, geostationary satellites are better for international communications and in 1974, the Soviets launched their first geostationary satellite. Since then, they have developed three different geostationary satellite systems: Raduga (1975), Ekran (1976), and Gorizont (1978). They have also launched geostationary satellites with experimental systems using higher frequencies. The Soviets now launch their own data relay satellites, and have used them (beginning in 1986) for data relay between their space station *Mir* and ground control. A full system like the U.S. TDRSS has not been deployed, however. They have also retained the old store/dump type of communications satellite for tactical and theater operations.

In their new efforts to offer commercial space products and services to earn hard currency, the Soviets have attempted to sell the use of Gorizont satellites, but these efforts have been unsuccessful because the satellites offer much less capacity and less sophisticated technology (for stationkeeping, for example) than Western satellites. They also are trying to develop and market commercial store/dump satellites systems (Coscon and Gonetz) and are contemplating development of several new geostationary communications satellite systems (Gals, Gelikon, Marafon, and a Soviet-German system called Romantis). In what may become a trend in the Soviet Union as republics assert their independence, in 1990 the Soviets launched a Gorizont satellite specifically for the republic of Russia.

Instead of joining INTELSAT, the Soviet Union formed INTERSPUTNIK in 1971 as a competitor. At its peak, 15 countries were members of INTERSPUTNIK, primarily members of the Soviet bloc plus Soviet allies. The dramatic changes in Eastern Europe in 1989 and 1990 have left the future of

INTERSPUTNIK in limbo as these countries now are free to turn to INTELSAT or regional communications satellite systems like Europe's EUTELSAT.

Many countries have their own dedicated communications satellites (in addition to using the INTELSAT system). After the Soviets, Canada was next to have a domestic communications satellite system, followed by the United States. Japan, India, Europe (collectively and individual countries), Indonesia, China, Mexico, Brazil, Australia, and the members of the Arab League are among those who have bought and/or launched their own communications satellites.

NAVIGATION

The United States has two navigation satellite systems. The older system is operated by the U.S. Navy. Originally called Transit, it was renamed the Navy Navigation Satellite System (the satellites are sometimes called Oscar) and provides two-dimensional data (latitude and longitude). The system is widely used by the civil sector in addition to its primary purpose of supporting military users.

The newer system is not yet fully operational, but was used extensively by U.S. and allied forces in the Persian Gulf conflict (see part 1, chapter 5), and is called the NAVSTAR Global Positioning System. NAVSTAR GPS can provide three-dimensional data (latitude, longitude, and altitude) 24 hours a day, anywhere on the globe, in all weather conditions. NAVSTAR GPS entered the testing phase in 1978 when four satellites were in orbit (the system ultimately requires a total of 18 satellites of which four must be in view of the user at one time in order to provide three-dimensional data; two dimensional data can be provided with fewer satellites), and will replace the Transit system once it is operational, currently expected in 1992. The satellites can operate at two levels of accuracy, a "coarse" level that tells users their position within 100 meters, and a "precise" level with 16 meter accuracy. Under normal circumstances, DOD plans to make the 100 meter channel available to civilian users, while the 16 meter channel will be available only to military users. Since the military NAVSTAR GPS receivers were not widely available at the time of the Persian Gulf War, however, civilian receivers were utilized by DOD and all users had access to the 16 meter channel. Civilian users want to continue to receive the more precise data, an issue currently receiving attention.

The Soviet Union has a navigation satellite system similar to Transit. Some of the satellites are used for civilian purpose and others for the military. At one time, the Soviets exhibited one of the civilian satellites at a conference with a placard stating its name as "Tsikada," although no satellite has had that designation. In 1989, the Soviets began naming these satellites "Nadezhda." The military satellites, apparently of the same design, simply receive a generic "Cosmos" designation like most other Soviet military satellites.

The Soviets are also developing a three-dimensional navigation satellite system like NAVSTAR. Their system is called "GLONASS," and the satellites

are launched three at a time. In 1989, two GLONASS launches involved only two GLONASS satellites, while the third in each case was a geodetic satellite designated Etalon. GLONASS satellites have been launched since 1982, but these are part of a developmental program; the Soviets expect the system (consisting of 24 satellites) to be fully operational in 1995.

The similarity between NAVSTAR GPS and GLONASS and their ability to produce altitude data in addition to latitude and longitude has led to plans by the International Civil Aviation Organization (ICAO) and other aviation groups to discuss the possibility of a global aircraft navigation system relying on both systems. Northwest Airlines and Honeywell are testing both NAVSTAR GPS and GLONASS receivers, and receivers that can use either system are being developed. Technical and policy issues remain to be resolved before the international aircraft community begin to rely on a joint system.

GEODESY AND MAPPING

The United States has flown many geodetic flights in the interest of tying together maps of different parts of the world and for basic scientific studies to understand better the true shape of the planet. (Such data are needed for many purposes, including missile targeting.) If there have been mapping flights as well, the results have not been published.

The Soviet Union is interested in both geodesy and mapping, but has made few public statements about such flights. Some flights in the Cosmos series have orbital characteristics which would support such missions. As noted above, two Etalon geodetic satellites were launched in 1989 in conjunction with GLONASS launches.

SEARCH AND RESCUE

In 1984, the Soviet Union and the members of SARSAT (the United States, Canada and France) signed an agreement providing for the operational phase of the COSPAS/SARSAT system which is used to locate ships and aircraft in distress. Transponders on Soviet navigation satellites and U.S. NOAA weather satellites pick up signals from emergency locator transmitters on ships and aircraft in distress and relay them to ground stations and control centers in the Soviet Union, United States, Canada, France, Norway and Britain from which rescue forces are deployed. The Soviet transponders are developed by the Soviets themselves and are called COSPAS; the transponders on the U.S. satellites are developed cooperatively by the United States, France, and Canada and are called SARSAT. INMARSAT serves as the secretariat for COSPAS/SARSAT.

METEOROLOGICAL SATELLITES

The United States has an operational weather satellite system using two satellites in Sun-synchronous polar orbits (called NOAA for the National Oceanic and Atmospheric Administration which operates them), and (normally) two Geostationary Operational Environmental Satellites (GOES) in geostationary orbit. (Each time a satellite in a Sun-synchronous orbit passes over any given location on Earth, it is precisely the same time as when it last passed over that site, e.g., 9:30 a.m., thus providing data with the same Sun angles which makes analysis of the data much easier.) NASA developed a low-cost ground terminal for receiving data from the polar orbiting satellites, called APT (automatic picture transmission) equipment, which is now available through a variety of companies to anyone in the world. The U.S. Department of Defense has its own polar orbiting weather satellites, called the Defense Meteorological Satellite Program (DMSP).

Only one GOES satellite is currently working, and problems have developed in building the next generation of GOES satellites (called GOES-NEXT) that may create a gap between when the existing satellite expires and a new satellite is launched. NOAA (part of the Department of Commerce) is looking at contingency plans that may involve using a European geostationary weather satellite for coverage of the east coast of the United States; Japan has geostationary weather satellites as well, although they do not provide all the same data as GOES.

The Soviet Union has polar orbiting weather satellites called Meteor, but these are not in Sun-synchronous orbits. The Soviets do not have geostationary weather satellites, although they had promised to launch such a satellite as part of an international weather program in 1979. Their current plans for the program, called GOMS, are unknown. In 1988, they launched a satellite with the generic Cosmos designation (Cosmos 1940) that has a meteorological role, but apparently it is not GOMS.

REMOTE SENSING

Remote sensing satellites are designed to look down at the Earth from space. Although weather satellites also fall into the category of remote sensing, the term is more often applied to satellites that provide data on mineral deposits, pollution sources, crop forecasting, land management, or the oceans, for example.

Since 1972, the United States has launched five Landsat satellites for land remote sensing. Data from the Landsat spacecraft are available on a non-discriminatory basis to anyone for a fee. The first three Landsats had 80 meter resolution; Landsat 4 and 5 have 30 meter resolution (resolution is the ability to "see" an object, so a 30 meter resolution means that you can detect objects larger than 30 meters in diameter).

The U.S. Government decided not to launch any more Landsat satellites, expecting the private sector to take over the program since the technology had become mature. Legislation passed Congress in 1984 (P.L. 98-365) to facilitate transfer of the remote sensing program to the private sector. NOAA (which has operational responsibility for the Landsat series as well as for the weather satellites) selected a contractor, EOSAT, to commercialize the system, but the "privatization" of Landsat was complicated by disputes between the Executive Branch and Congress over promised Government subsidies to EOSAT. The issue was especially controversial in 1989, and was reviewed by the National Space Council which decided that the U.S. Government would support the Landsat program. The Space Council and Congress are assessing the various alternatives for continuing the system. EOSAT is building the sixth Landsat satellite, and it appears likely that a government agency (NASA, NOAA or DOD) will assume responsibility for building future satellites. Who will market/distribute the data remains an open question. France, which developed the SPOT satellite with 10 meter resolution, and the Soviets (see below) also offer remote sensing data on a commercial basis. The French and Soviet systems produce data that complement, not duplicate, Landsat data.

The United States also pioneered in ocean remote sensing. In 1978, SEASAT was launched carrying a synthetic aperture radar (SAR) and other instruments to make oceanographic observations and measurements (ocean waves, ice fields, coastal conditions, surface temperature, and others). The spacecraft suffered a malfunction after only 100 days in orbit, however. Similar radars were flown on the space shuttle (SIR-A and SIR-B) and additional flights are planned. The shuttle can stay in orbit for only 7-10 days, however. Attempts to build a follow-on to SEASAT failed because of budgetary considerations. NASA developed an instrument, called a scatterometer, that was to have flown on one of the proposed follow-on satellites. That instrument, now designated NSCAT (NASA Scatterometer), is expected to be flown on a Japanese spacecraft called ADEOS in 1995. NASA is also working on the TOPEX (Ocean Topography Experiment) program in conjunction with France.

The Soviet Union has developed a great interest in remote sensing. Crews on *Salyut 6* and *7* from 1977-1986 spent a considerable amount of time performing Earth resources investigations with a variety of cameras, including a six channel multispectral camera (MKF-6M) developed by East Germany. Although the MKF-6M is not installed on the new *Mir* space station, the crews do perform some remote sensing observations using hand held cameras and a topographic camera called KATE-140, which was also used on *Salyut*. The Soviets plan to launch a module to dock with *Mir* that is devoted to remote sensing studies called *Priroda* in 1991 or 1992.

The Soviets also have launched several experimental Landsat-type satellites in the *Resurs-O* series. A third series of remote sensing flights, *Resurs-F*, uses satellites that are indistinguishable from military reconnaissance flights in terms of orbital parameters and lifetimes. The spacecraft remain in orbit for only two to four weeks, after which a capsule containing exposed film is deorbited. Although some Western analysts count these as reconnaissance rather than

Earth resources missions, this report classifies them as remote sensing since there is no logical reason for the Soviets to specify that these flights, in particular, are for remote sensing, when ordinarily they would simply say nothing about their mission. Also, the Soviets now offer data from these satellites on the commercial market. Although the Soviet data have 5 meter resolution, the best on the market, they have had only limited success in selling the photographs, perhaps because the data are not in digital form like Landsat and SPOT.

In 1987, the Soviets launched a large satellite, Cosmos 1870, or Resurs-R, which carried a SAR. The satellite was about the same size as a *Salyut* space station (or the *Mir* core module). At the end of its two-year lifetime, the Soviets announced that it was the first of a series of SAR-equipped satellites called Almaz. The first satellite named Almaz was launched in March 1991. The Soviets also launch satellites with side-looking radars (SLRs) called Okean-O for remote sensing of the oceans and especially for guiding ships through the Arctic Ocean.

MISSION TO PLANET EARTH AND THE EARTH OBSERVING SYSTEM

NASA and the world's scientific community are initiating a program called Mission to Planet Earth (MPE), which will provide data to help scientists better understand the Earth as a total system and what effect the human population has on the planet. Generically, this field of study is called "Global Change" research and includes such topics such as global warming, ozone depletion, and deforestation. The international scientific effort to study Global Change is called the International Geosphere-Biosphere Program (IGBP).

NASA defines MPE as certain satellites and associated data systems needed to provide data for the Global Change program. Ultimately, NASA plans to have four large, multipurpose spacecraft called "platforms" in polar orbit (around Earth's poles), five platforms in geostationary orbit (35,800 kilometers above the Equator, where a satellite maintains a fixed position relative to any point on Earth), plus a variety of other satellites in different orbits from which special observations can be made (called "Earth Probes"). The geostationary platforms are not part of NASA's current budget plans. Thus, NASA now defines MPE as the polar platforms (called the **Earth Observing System**), the Earth Probes, and associated data systems. NASA plans to provide two of the polar platforms (until 1989 they were part of the space station program, but now are separate), with the third from Europe, and the fourth from Japan. These countries and others (including the Soviet Union), individually or cooperatively, are planning other spacecraft that will contribute data to the Global Change research program. For example, the U.S. Upper Atmosphere Research Satellite (UARS), the U.S./French Ocean Topography Experiment (TOPEX), the European Earth Remote Sensing (ERS) satellite, the Japanese ERS (JERS) satellite and Advanced Earth Observing System (ADEOS) platform are all related to studies of the Earth and its environment.

Mission to Planet Earth is controversial because of its expected cost of \$30 billion over its lifetime, and because of disagreement as to whether the large platforms are preferable to smaller satellites for carrying the instruments. For further information, see CRS Issue Brief 87018, *Space Policy*; CRS Report 90-300 SPR, *Mission to Planet Earth and the U.S. Global Change Research Program*; and CRS Report 91-89, *Mission to Planet Earth*.

CHAPTER 4

SPACE SCIENCE

Both the United States and the Soviet Union have sent probes to fly-by, orbit, and/or land on other planets. Other probes investigate the interplanetary medium and/or comets. So far, the United States has sent probes to Mercury, Venus, the Moon, Mars, Jupiter, Saturn, Uranus, and Neptune. The Soviet Union has sent probes to Venus, the Moon, and Mars. A U.S. probe already in space was diverted to investigate a comet in 1985; two Soviet probes intercepted Halley's Comet in 1986 (along with spacecraft from Japan and Europe). The United States and Soviet Union also have extensive programs for studying Earth's atmosphere, the interaction between the Earth and the Sun (solar-terrestrial relationships), and the universe using spacecraft in earth orbit.

EARTH-ORBITAL SPACE SCIENCE

The history of Earth-orbiting satellites for space science studies began with the very first launches of spacecraft. As discussed at the beginning of this report, the decision to launch satellites was made as part of the International Geophysical Year (IGY), and both Sputnik 1 and Explorer 1 were launched in support of the IGY.

The United States has conducted a large number of launches of Earth-orbiting space science missions. The Explorer program is a continuing series of small satellites devoted to a particular scientific goal. Many of the Explorer missions involve international participation, and over 60 Explorer satellites have been flown. Some study the interaction between the Sun and Earth in disciplines such as air density, energetic particles, ionospheric research, magnetospheric research, and solar physics. Other Explorer satellites are dedicated to astronomy, including wavelengths in the x-ray, gamma-ray, ultraviolet, and radio ranges. Larger observatory-class satellites have also been launched by the United States. To date, these have included the Orbiting Geophysical Observatory (OGO), Orbiting Solar Observatory (OSO), Orbiting Astronomical Observatory (OAO), and High Energy Astronomy Observatory (HEAO) programs. NASA is now embarked upon the "Great Observatory" program, consisting of four large space observatories. Two have been launched already: the Hubble Space Telescope for the visible and ultraviolet wavelengths, and the Gamma Ray Observatory. The third and fourth are expected to be launched in the mid- to late-1990s (see *Future U.S. and Soviet Space Science Missions* below). As noted in the *Summary of Recent Activities*, problems with the Hubble's main mirror were discovered after the satellite was launched. NASA hopes to remedy the problem in 1993 or 1994.

The Soviet Union launched its first geophysical observatory in 1958 (Sputnik 3), but has not used Earth orbit as a base for free-flying scientific spacecraft as extensively as the United States. Until the late 1980s, most Soviet scientific satellites were designated simply as Cosmos flights and few details are released about them. Projects involving international cooperation, such as those developed under the Intercosmos program, receive broader distribution of results. As more and more Soviet space science projects have included international partners, more information is generally available.

The Prognoz program, of which there have been 10 flights since 1971, is the closest the Soviets have come to observatory-class spacecraft performing multiple missions. The first eight of these concentrated on atmospheric studies, and Prognoz 10 made magnetospheric studies. Prognoz 9, launched in 1983, performed radio astronomy research. Also in 1983, the Soviets launched the Astron satellite, a large observatory-class satellite which performed research in the x-ray and ultraviolet wavelengths. Granat, launched in 1989, will continue astronomical research in the x-ray and gamma ray bands. Gamma-1, a Soviet-French satellite launched in 1990, is devoted to gamma ray observations.

Space science research has also been conducted on the space stations launched by both the United States and Soviet Union. For example, the U.S. Skylab carried the Apollo Telescope Mount dedicated to studies of the Sun, and a radio telescope was deployed from the Soviet *Salyut 6*. For the Soviets, the launch of the Kvant module to *Mir* in 1987 ushered in a new era of space station astronomical observations. Kvant incorporates instruments for both gamma-ray and x-ray astronomy, and the module appears to be a permanent part of the space station complex. During 1987, the Soviets made many observations of the supernova in the Large Magellanic Cloud discovered by ground-based observers at the Cerro-Tololo Observatory in Chile. The Soviets also perform wide-ranging atmospheric studies using instruments on their space stations, and plan to launch a module dedicated to atmospheric observations (called either Optizon or Spektr) in 1991 or 1992 to dock with their current space station *Mir*.

AUTOMATED LUNAR EXPLORATION

The first attempts to send spacecraft to the Moon were either fly-bys or probes that were intended to strike the Moon without surviving the impact. In 1958, the United States began a double series of Pioneer flights—one to photograph the far side of the Moon and the other to fly by it. All four launch attempts in that year failed to reach the Moon. In January 1959, the Soviets launched Luna 1 which apparently missed the Moon. The United States followed in March 1959 with Pioneer 4 which went by the Moon and circled the Sun. U.S. plans then were to follow up with four more, larger Pioneer series lunar orbit flights during the course of 1959 and 1960, but all of these failed to reach even Earth orbit. In fact, a U.S. probe did not reach the Moon until Ranger 4 impacted the far side in 1962.

In September 1959, the Soviet Luna 2 struck the Moon near its visible center, delivering metal plaques bearing the Soviet coat of arms. In October 1959, Luna 3 flew by the Moon and took photographs of the far side, never seen before, which were returned to Earth by radio facsimile. Still later, the U.S. Ranger 7, 8, and 9 flights (1964-1965) returned spectacular TV pictures of the Moon up to the moment that they impacted the lunar surface.

The next phase of automated lunar exploration used spacecraft to make survivable landings. The seven U.S. Surveyor spacecraft (1966-1968) returned almost 100,000 pictures of the lunar surface and dug holes in the surface by remote control to determine the chemical composition of the lunar soil.

The Soviet Union attempted landings as early as 1963, but later admitted that Luna 4, 5, 6, 7, and 8 failed to achieve a survivable landing. Additionally, one unnamed flight and Cosmos 60 were lunar failures which did not leave Earth orbit. When Luna 9 in 1966 finally reached the surface, its television camera returned 27 pictures of the surroundings--the first pictures from the surface of another solar system body. Luna 13 performed impact testing of the soil with an extendable arm.

Orbiters were used at about the same time as the landers. The Soviet Luna 10 was the first spacecraft to achieve a successful lunar orbit (1966) and returned data about the composition of the lunar surface and gravity anomalies. Luna 12 in 1966 finally returned a few pictures to supplement earlier Soviet pictures taken of the far side by Luna 3 in 1959 and Zond 3 in 1965. Luna 14 (1968) was an extension of the work of Luna 10, neither of which took pictures. The five U.S. Lunar Orbiters (1966-1967) returned extensive data about the lunar surface that were used to select landing sites for the Apollo missions.

The Apollo landings (see part 1, chapter 2) followed the U.S. automated lunar program, and no further automated lunar missions have been launched by the United States. The Soviets continued to launch lunar probes until 1976. Zond 5 and 6, the 1968 automated precursors to projected later piloted flights, returned actual photographs to Earth in the same manner as Apollo 8. Zond 7 in 1969 and Zond 8 in 1970 performed tasks similar to those of the two preceding Zonds. Heavier satellites were placed in lunar orbit (Luna 19 in 1971 and Luna 22 in 1974) which remained under active control for more than a year, gathering a wide variety of data and some pictures.

The Soviet Union launched two special types of lunar vehicles for exploration of the Moon in lieu of human crews. Three missions (Luna 16 in 1970, Luna 20 in 1972, and Luna 24 in 1976) returned a total of approximately 330 grams of lunar material to Earth (compared with 380 kilograms returned by the U.S. Apollo crews). Three other flights that may have been intended to return samples failed (Luna 15, 18, and 23).

The other special Soviet program placed roving vehicles called Lunokhods on the lunar surface. Lunokhod 1 (Luna 17) landed on November 17, 1970, and continued to function until October 4, 1971, traveling 10,540 meters over the

surface, and returning 20,000 television views, 200 detailed panoramas, 500 soil-property tests, 25 soil chemical analyses, and a number of astronomical observations with its x-ray telescope. Lunokhod 2 (Luna 21) in 1973 operated for 3 months, but traveled 37,000 meters in that time, and returned proportionately more data and pictures despite its shorter life.

U.S. PLANETARY MISSIONS

The U.S. Mariner program of three-axis stabilized probes involved the launch of ten vehicles, six of which returned planetary data. Mariner 2 and 5 brought back indirect readings of Venus. Mariner 4, 6, 7, and 9 brought back increasingly good pictures of the surface features of Mars. Mariner 10 not only returned good pictures of the cloud patterns of Venus, but made three photographic passes by Mercury.

The Pioneer series of spin-stabilized spacecraft has seen 18 launch attempts, of which 12 were at least partially successful. Pioneer 1 and 3 did not reach their intended trajectories to the Moon, but did send back data about Earth's atmosphere. Pioneer 4 successfully returned data as it flew past the Moon and entered heliocentric orbit. Pioneers 5 through 9 studied the area of space between the Earth and Sun.

Pioneers 10 and 11 were the first planetary probes of the Pioneer series, and were launched to investigate Jupiter, Saturn, and the interplanetary medium. Both probes sent back pictures of Jupiter in 1973 and 1974 respectively; Pioneer 10 then was placed on a trajectory out of the solar system, while Pioneer 11 continued on to a successful encounter with Saturn in 1979. In 1983, Pioneer 10 passed out of the solar system, the first object from planet Earth to do so, and continues to return data.

Pioneer Venus 1 and 2 were launched in 1978 and reached Venus in December of that year. Pioneer Venus 1 is an orbiter, which continues to return data about Venus, and in 1986 also was used to collect data about Halley's Comet. Pioneer Venus 2 consisted of five separate probes, all of which descended through the Venusian atmosphere to make in situ measurements of its characteristics. Although they were not designed to withstand landings on the planet, two of the probes did survive and transmitted data for as long as 67 minutes after impact.

Viking 1 and 2, launched in 1975, each were orbiter/lander combinations. The orbiters mapped the surface of Mars and collected clear views of Deimos and Phobos, the two Martian moons. The landers sent back color pictures from the surface, and their on-board laboratories conducted a search for life with inconclusive results. The last of the Viking spacecraft (the Viking 1 orbiter) returned data until 1983. NASA has now turned ownership of that lander over to the Smithsonian Museum.

Voyager 1 and 2 were launched in 1977 toward Jupiter and the outer planets. During 1979, they returned astonishing color pictures not only of

Jupiter, but also of its larger moons, each unique and unexpected in appearance. In 1980, Voyager 1 returned equally exciting pictures of Saturn and its moons, including Titan, and Voyager 2 returned data on Saturn in 1981. Voyager 2 reached Uranus in January 1986 and Neptune in August 1989, returning more data to astound Earth-bound scientists.

In 1989, NASA launched the Magellan mission to Venus, where it arrived in August 1990. Magellan carries a synthetic aperture radar for mapping the Venusian surface. NASA also launched the Galileo probe to Jupiter in 1989; it will arrive there in 1995. One section of the spacecraft will descend through Jupiter's atmosphere, while another will orbit the planet and then make a tour of several of Jupiter's moons.

The United States has had several probes to investigate the interplanetary medium. One of special note was launched in 1978 as International Sun-Earth Explorer 3, part of a series of satellites for studying solar-terrestrial relationships. In 1983, it was redesignated ICE, or International Cometary Explorer, and was moved from its position between the Earth and the Sun to fly by Comet Giacobini-Zinner in September 1985. Data from this encounter is being compared with that obtained by other spacecraft about Comet Halley. The United States did not have a probe for the Halley's Comet encounter.

SOVIET PLANETARY MISSIONS

In 1961, the Soviets launched their first Venus probe, Venera 1, but it was not operating when it reached the planet. In 1962, there were three more Venus attempts and three Mars attempts, with five of these payloads stranded in Earth orbit, and the sixth, Mars 1, not operating when it reached the vicinity of that planet. Zond 1, Venera 2, and Venera 3 were not in operating condition when they reached Venus. Zond 2 made a close fly-by of Mars in a non-operating condition. Zond 3 was a test flight which took pictures of the far side of the Moon and rebroadcast them to Earth as it traveled as far as the orbit of Mars.

Results improved for the Soviets when Venera 4, 5, 6, 7 and 8 all functioned and returned direct readings of Venus' atmosphere. Venera 7 survived a Venus landing and broadcast for 23 minutes from the surface. Venera 8 had similar success, plus performing soil analyses.

In 1975, two larger Soviet Venus probes, Venera 9 and 10, reached their destination and became the first spacecraft to return pictures from the surface of another planet. The orbiters returned pictures and other data for many months in orbit. The landers operated for about an hour on the surface, and their cameras returned good pictures of the far side surface, relayed via the orbiters. This was a remarkable feat, considering the 485°C temperature and surface pressure 90 times that on Earth.

Venera 11 and 12 were sent to Venus in 1978, at approximately the same time as the U.S. Pioneer-Venus probes. No photographs were returned by these spacecraft, and Soviet scientists have indicated that the imaging systems failed.

Data were returned on other aspects of the Venusian atmosphere and surface. Venera 13 and 14 landed in 1982 and sent back color photographs of the surface, and used drills to obtain core samples for chemical analysis.

In 1983, the Soviets launched Venera 15 and 16 which, instead of carrying the traditional landers, were equipped with side-looking radars to study the surface of Venus from orbit. Venera 15 entered orbit around Venus on October 10, followed four days later by Venera 16. The radars had a resolution of 1-2 kilometers, and were in polar orbits around the planet to provide data on parts of the planet not seen by the U.S. Pioneer-Venus orbiter or from Earth-based telescopes.

In December 1984, the Soviets launched two VEGA spacecraft to study both Venus and Halley's Comet. At Venus, the two spacecraft dropped off landers and balloons developed by French scientists which slowly drifted through Venus' atmosphere to make in situ measurements. The main part of each spacecraft continued on to an encounter with Halley's Comet in March 1986. VEGA 1 was the first probe to arrive there; others were launched by the European Space Agency and Japan.

The Soviets have been plagued with problems in their Mars program. In 1971, two orbiter/lander spacecraft, Mars 2 and 3, were launched. Mars 2 landed on the surface but no further mention was made of it by the Soviets, suggesting that it failed; Mars 3 made a survivable landing, but signals ceased after 20 seconds, before the first complete picture was received on Earth. The orbiters did return data. In 1973, four spacecraft (Mars 4, 5, 6 and 7) were launched. Mars 4 and 5 were intended as orbiters working with the Mars 6 and 7 landers. Of these four only Mars 5 attained an orbit and Mars 6 a landing. Mars 6 returned direct readings within the atmosphere, but signals ceased before it reached the surface. Thus, of all these missions, only Mars 5 can be counted as a complete success by Western standards.

In June 1988, after a 15 year hiatus in sending probes to Mars, the Soviets launched two Mars probes, Phobos 1 and 2. The spacecraft included a large number of international experiments, and were almost identical. The primary objective for the Phobos project was to study Phobos, one of the two moons of Mars, although studies also were to be made of Mars itself. The bad luck indicative of the Soviet Mars exploration program evidenced itself with this project as well. On August 29, 1988, a Soviet ground controller sent an incorrect command to Phobos 1, telling it to turn off its stabilization systems. The error was not detected until three days later when attempts at contacting the spacecraft were unsuccessful. The Soviets speculate that with the attitude stabilization system turned off, the spacecraft no longer maintained its correct orientation toward the Sun to keep the batteries charged, and the spacecraft died.

Phobos 2 completed its journey to Mars uneventfully, reaching Martian orbit at the end of January 1989. The probe successfully returned data about Mars, but as it was maneuvering to make its studies of Phobos, contact was lost

with the spacecraft. The Soviets have narrowed the cause to three possibilities, but feel they may never know exactly what happened. Thus, Phobos 2 failed in its primary objective (studying Phobos), but was successful in returning data about Mars and thus is categorized as a partial success.

FUTURE U.S. AND SOVIET SPACE SCIENCE MISSIONS

As noted, the Hubble Space Telescope and the Gamma Ray Observatory are the first two of NASA's four "Great Observatories." Third is the Advanced X-Ray Astrophysics Facility (AXAF), and last is the Space Infrared Telescope Facility (SIRTF). AXAF is under construction and is expected to be launched in the mid-1990s; funding for SIRTF has not been requested yet, but NASA hopes to put it in orbit before the end of the decade.

More Explorer satellites are also being planned by NASA, and Congress has increased funds for the Explorer program in recent years to provide more flight opportunities for scientists (the satellites are relatively inexpensive and easy to produce compared to observatory-class spacecraft). EUVE (Extreme Ultraviolet Explorer) and XTE (X-Ray Timing Explorer) are planned next.

An international armada of Earth-orbiting satellites is being planned to support the International Solar-Terrestrial Physics (ISTP) program to further study the interaction between the Sun and the Earth. The U.S. contribution to ISTP is called the Global Geospace Science (GGS) program and involves the launch of two spacecraft called Wind and Polar. Japan is building one spacecraft (Geotail) and Europe is providing two (Cluster and SOHO), all scheduled to be launched in 1992-1993.

In 1992, the United States plans to launch Mars Observer, a probe for geophysical and climate studies of Mars. Two new planetary missions were begun in 1989: the Comet Rendezvous-Asteroid Flyby Mission (CRAF) and Cassini, to study Saturn and its moon, Titan. The two probes will use the same spacecraft design and were requested jointly by NASA, so are often referred to as though they were one project--CRAF/Cassini.

Magellan, Mars Observer, CRAF and Cassini were all recommended as the "core program" by NASA's Solar System Exploration Committee, which issued two reports (in 1983 and 1986) on the future of U.S. planetary exploration. NASA relies on internal and external advisory committees to prioritize space science objectives. In addition to its own SSEC, NASA uses the National Academy of Sciences to prepare advisory reports. In 1988, for example, the Academy released a 7-volume study entitled *Space Science in the 21st Century: Imperatives for the Decades 1995-2015*. The missions identified in these committee reports are proposals, not approved programs; it is up to NASA to ultimately decide which programs to request funding for and in what order.

In October 1987, at celebrations marking the 30th anniversary of the launch of Sputnik, the Soviets announced broad proposals for planetary exploration that caused great concern among their Western colleagues.

Although the Soviets emphasized that they were only proposals, not plans, some Western planetary scientists characterized the Soviet announcement as an indication that the Soviet Union was achieving a leadership position in planetary exploration.

In the intervening years, the Soviet proposals have been changed and scaled down considerably, probably because of additional discussions inside the Soviet planetary science community, coupled a deteriorating budget situation. In August 1989, the Soviets listed the following missions as possibilities for the next 15 years: Mars '94 which would involve an orbiter, surface penetrators, surface rover, and French-made balloons; Mars-Aster '96, to fulfill some of the objectives of the Phobos missions and to study the asteroid belt; Mars '98, to land rovers on Mars; Mars 2001, to return samples of Martian soil to Earth; and an unnamed mission to Mercury in 2003. The Soviets have made clear that only Mars '94 is an approved program, and in the spring of 1991, even that mission was altered to account for new budgetary realities. While they still plan a Mars '94 mission, some of the experiments (including the rover and balloons) will be deferred to a separate mission now proposed for launch in 1996.

The Soviets are also planning additional Earth-orbiting scientific satellites. Among them are: Interbol, a magnetospheric research mission which will involve the launch of two satellites, each with a Czechoslovakian sub-satellite, in the early 1990s; CORONAS (comprehensive study of solar activity from near-earth orbit) for launch in the early 1990s to study solar eruptions; Spectrum-X/Gamma for observations in the ultraviolet, x-ray and gamma ray bands, for launch in 1993 (20 countries, including the United States, are participating in this project); and Radioastron, a group of three radio astronomy satellites planned for launch in 1995-1997.

Many scientists are interested in the possibility of U.S./Soviet cooperation in space. One specific proposal is that the United States send a rover to Mars that would roam about the surface collecting samples from various locations. The rover would bring the samples back to a Soviet spacecraft that would return them to the vicinity of Earth for analysis (they probably would not be brought back to Earth itself because of contamination concerns). This is not yet an approved mission by either country, although each is conducting independent rover/sample return design studies. From the U.S. standpoint, a joint mission would avoid many problems such as technology transfer, since the only place the probes need to be compatible is on the surface of Mars. Also, if either country withdrew from the program for economic, technical, or political reasons, the other would still have a viable scientific mission. On the other hand, a 1990 report by the U.S. National Academy of Sciences (*International Cooperation for Mars Exploration and Sample Return*) recommended caution in pursuing joint missions, suggesting that, at first, the two countries simply try to coordinate Mars missions; if successful, the relationship could evolve into cooperative missions.

CHAPTER 5

MILITARY SPACE ACTIVITIES

MILITARY VERSUS CIVIL SPACE MISSIONS

Both the U.S. and Soviet space programs have strong military components. The distinction between military and civilian launches is arbitrary to a certain extent, since any satellite can be used for either sector. For example, communications satellites can carry either military or civilian traffic, and navigation satellites are used by both the military and civilian communities.

When attempting to construct a list of military versus civilian launches, such as table 4, determining which sector will be primarily served by a satellite is complicated. The Soviets, for example, ordinarily do not announce the mission of satellites designated "Cosmos" which comprise a substantial fraction of their annual launches. Western analysts of the Soviet program assess the mission of these satellites based on factors such as telemetry, past experience, and the likely nature of a satellite using a particular orbit. In the United States, missions for Department of Defense satellites are rarely revealed and even when they are, categorizing them as military or civilian can be complex. For example, Transit navigation satellites are developed by the Navy for its own use, but more than 90 percent of the system's users are civilian. Clearly, distinguishing between military and civilian satellites is an inexact art.

The process is even more difficult since table 4 reflects launches rather than individual satellites. The U.S. space shuttle may launch several payloads at one time, and other experiments may take place on the shuttle itself. A Defense Satellite Communications System (DSCS) communications satellite launched from the shuttle would be classified as military, but if the predominant nature of the shuttle mission is civilian, it will be listed as a civilian launch in the table. Only those shuttle missions dedicated to DOD use are counted as military. These difficulties should be borne in mind when using the table.

MILITARY SPACE PROGRAMS

Military satellites are, for the most part, non-aggressive. In fact, their missions are hardly distinguishable from missions conducted for civilian application purposes. Both countries have military satellites for communications, weather, navigation, geodesy, and various types of reconnaissance (photographic, electronic intelligence, nuclear explosion detection, early warning, and ocean surveillance).

TABLE 4.
Approximate Comparison of U.S. and Soviet Successful
Launches: Primarily Civil Versus Primarily Military*

YEAR	PRIMARILY CIVIL		PRIMARILY MILITARY	
	U.S.	U.S.S.R.	U.S.	U.S.S.R.
1957	0	2	0	0
1958	5	1	0	0
1959	5	3	5	0
1960	6	3	10	0
1961	10	6	19	0
1962	21	15	31	5
1963	12	10	26	7
1964	25	15	32	15
1965	35	23	28	25
1966	41	17	32	27
1967	34	20	24	46
1968	25	25	20	49
1969	24	19	16	51
1970	14	26	15	55
1971	22	23	10	60
1972	20	21	11	53
1973	15	28	8	58
1974	18	29	6	52
1975	21	29	7	60
1976	19	25	7	74
1977	15	29	9	69
1978	24	28	8	60
1979	12	27	4	60
1980	8	25	5	64
1981	13	39	5	59
1982	12	33	5	68
1983	15	40	7	58
1984	10	34	12	63
1985	11	33	6	64
1986	3	28	3	63
1987	2	33	6	62
1988	6	37	6	53
1989	5	32	13	42
1990	14	30	13	45
TOTAL	522	788	410	1,467

* See text for cautionary statements about use of this table.

Prepared by CRS.

The only generic type of satellite that the Soviets have for which there is no corresponding U.S. system is radar ocean reconnaissance satellites (RORSATs) which use radars to monitor the ships at sea (press reports indicate that the United States launched a radar satellite, *Lacrosse*, in 1989, but it is not clear if it is dedicated to ship surveillance). The Soviet radars require a great deal of power and the Soviets use nuclear reactors on the satellites to provide that power. For safety reasons, the portion of the satellite containing the nuclear reactor is separated from the rest of the spacecraft after the mission is over and boosted into a high orbit from which it will not return to Earth until the radioactivity has subsided (hundreds of years). In two cases, however, the system malfunctioned. In 1978, *Cosmos 954* reentered prematurely and spread radioactive material over northern Canada. In 1983, *Cosmos 1402* reentered in two pieces over the Indian Ocean and the South Atlantic. No increase in radioactivity was detected in either area. There was another RORSAT malfunction in 1988 (*Cosmos 1900*). In April, the Soviets lost communication with the satellite, and could not command the reactor portion to be boosted into the higher orbit. In October, as the orbit decayed and the satellite reached the dense layers of the upper atmosphere, a fail-safe system was automatically triggered and the reactor was, in fact, boosted to the "safe" orbit. No RORSATs have been launched since.

Although the U.S. Government is reluctant to talk about military space activities, a considerable amount of information has appeared in the public literature. In some cases, Government officials have given public statements concerning these activities as well. For example, on March 15, 1967, President Johnson, speaking in Nashville, Tennessee asserted in an "off-the-record" statement widely reported at the time that the dividends of military space operations to the United States were equal to ten times everything which had been spent on space. This implied savings in the defense budget over a ten year period on the order of \$400 billion, because of more precise information about military and related activities all over the world. President Carter on October 1, 1978, officially acknowledged the U.S. role in military photo-reconnaissance from space.

The Soviets publicly acknowledged the existence of their military space program in 1985, but are also reticent to discuss it in detail. *Glasnost* and the need to justify space expenditures apparently is affecting even military programs, however, and some information is now forthcoming. In May 1989, a Soviet official stated that one of the uses for the space shuttle *Buran* could be to service "optoelectronic and radar reconnaissance satellites." Two months later, the Defense Ministry's chief specialist on missile and space systems, A. Maksimov, discussed the value of the Soviet military space program in an interview with *Krasnaya Zvezda*. Maksimov stated that reconnaissance satellites have 0.2-0.3 meter resolution, meaning "that from orbit it is possible . . . to determine whether a bomber of the B-1 type is equipped with missiles . . ." He added that "the implementation of military space programs alone will enhance our Armed Forces' combat efficiency 50-100 percent. The role of national space reconnaissance means increase particularly with the adoption of a defensive doctrine."

SATELLITES IN SUPPORT OF THE PERSIAN GULF WAR

The Persian Gulf War was the first major military conflict in which the United States and its allies could utilize a broad array of satellite assets. Although satellites have played important roles in recent limited military actions, the last major conflict, Vietnam, occurred too early in the Space Age to test the utility of space systems to U.S. and allied strategic and tactical commanders in time of war.

Satellites are often viewed more as strategic than tactical assets. Their role as "peacekeepers," monitoring arms control agreements or giving early warning of missile launches, are relatively well known, while their use for communications, weather, and navigation is less visible, but equally vital. In the Persian Gulf War, the full inventory of DOD and intelligence satellites played a significant role in the strategic conduct of the war, from providing communications between the National Command Authority (in the United States) and Central Command (in the Persian Gulf), to warning of Scud missile attacks, to watching troop movements. Their tactical value also was proven. Satellites provided photographic, radar, and electronic intelligence not only to top military leaders at Central Command headquarters, but to those in the field, too.

Among the U.S. military satellite systems used extensively were those for early warning of Scud missile launches (the Defense Support Program--DSP); U.S. and allied communications satellites (Defense Satellite Communication System--DSCS, Fleet Satellite Communication--FLTSATCOM, Satellite Data System--SDS, and Leasat); weather (Defense Meteorological Satellite Program--DMSP); navigation (NAVSTAR Global Positioning System--GPS); and photographic and electronic reconnaissance. (See CRS Report 91-215 SPR, *Military and Civilian Satellites in Support of Allied Forces in the Persian Gulf War* for further information.)

Perhaps the most publicly praised example of the utility of satellites in the Persian Gulf was the NAVSTAR GPS system which allowed air, land and ground forces to determine their location precisely and to navigate in a largely featureless terrain. Though still not completely operational, the system was used extensively and proved so vital that some troops reportedly wrote home asking relatives to send them the small hand-held receivers (called SLUGGERS) needed to access the system. Though developed by DOD, NAVSTAR GPS was always intended for use by the civilian sector as well and commercial receivers have been available for several years. Supplies of military receivers were not ready, so DOD "made do" with the commercial version, even though that meant they had to allow the commercial receivers to access the more precise channel intended only for military users (see *Navigation Satellites* in part 1, chapter 3).

SPACE WEAPONS

There is one special category of military space activities which can be described as "aggressive" and this is space weapons. Considerable debate has

developed as to whether space weapons, either those based in space for use against ground, air or space targets, or those based in the air or on the ground for use against space targets, will lead to greater or less stability between the superpowers. Although they have become a matter of substantial debate only in the past several years, space weapons have existed since the earliest days of the space program.

Early U.S. and Soviet Antisatellite Programs

The first test of an antisatellite (ASAT) device was conducted by the United States in 1959. A Bold Orion air-launched missile was used to score a deliberate near miss on the U.S. Explorer 6 satellite. Although the Bold Orion was not pursued as an ASAT device, the United States did have plans for a program called SAINT (variously described as having stood for SATellite INSpecTor, SATellite INTerceptor, or SATellite Inspection and NegaTion) from 1960-1962, but this program also was canceled.

In 1962, Nikita Khrushchev stated in an interview with American newspaper editors that the Soviet Union had a missile that could "hit a fly in outer space." This was interpreted by some as an indication of an ASAT capability, perhaps using Galosh antiballistic missiles. Perhaps in response to this concern, or perhaps because of the FOBS program (see below), the United States developed its own ASAT system using missiles based on Johnston Island and Kwajalein Atoll in the Pacific. The system at Kwajalein, which used Nike-Zeus missiles, was terminated in 1964, while the Johnston Island system, using Thor missiles, was declared operational by President Johnson in a 1964 speech. These facilities are believed to have been shut down in 1975. Since the system employed nuclear warheads, its use would have violated the 1963 Limited Test Ban Treaty and the 1967 Outer Space Treaty. The Soviet Galosh system may still be capable of intercepting satellites to about the same degree as the United States could have from its mid-Pacific installation, and similarly would violate the 1963 and 1967 treaties if used.

The Soviet Co-Orbital ASAT Device

Beginning in 1968, the Soviets began testing a co-orbital ASAT device; a total of 20 tests have been conducted so far. The most recent test was in June 1982, and the Soviet Union subsequently announced a unilateral moratorium on ASAT testing, stating that it will not be the first to place ASAT weapons in orbit (but avoiding any admission that they had already tested an ASAT device). The interceptor is launched by a variant of the Cyclone (F) booster and goes into a close co-orbit with the target satellite. In operation, the interceptor would then maneuver close to the target and explode (using a chemical explosive), destroying the operational capability of the target with shrapnel.

Tests were conducted from 1968 to 1971, after which a four-year hiatus occurred. Testing resumed in 1976, the year after the U.S. dismantled its missile ASAT system, and the Chinese had orbited their first prototype reconnaissance satellite. Whether these factors led to the resumption in testing

is unclear. One of the 1976 tests introduced a new type of homing device (optical rather than radar), that ultimately was tested six times, all of which failed. Nine of the 14 tests using radar guidance were successful (64 percent). The United States declared the Soviet system operational in 1977 and decided to develop its own advanced ASAT (see next section). At the same time, President Carter called on the Soviets to negotiate a treaty to ban weapons from space, and during the course of those talks in 1978-1979, the Soviets once again ceased tests of their ASAT device. When the negotiations ended (following the Soviet invasion of Afghanistan in late 1979), the ASAT tests resumed, with one test in 1980, two in 1981, and one in 1982. DOD asserts that the Soviets today have 16 ASAT interceptors that could destroy 10 U.S. or allied satellites in two days. Whether or not this system should still be considered operational, after more than eight years of dormancy and a modest success rate, is open to question.

The Soviet system is limited by the altitudes and inclinations at which it can be used. U.S. reconnaissance and remote sensing satellites, the space shuttle, some navigation satellites (the older Transit system) and some weather satellites (those in polar orbits) are within range. U.S. communications and early warning satellites and the newer NAVSTAR GPS navigation satellites are outside the range of the Soviet co-orbital ASAT, although future developments (such as using a more capable launch vehicle) could enhance that range.

U.S. F-15 Miniature Homing Vehicle ASAT Device

In 1977, following the Pentagon's assessment that the Soviet ASAT system was operational, President Carter authorized DOD to develop a U.S. ASAT device. Unlike the Soviet system, which is launched from the ground like a typical satellite, the U.S. decided to develop a system using a Miniature Homing Vehicle (MHV) launched from a two-stage rocket attached to an F-15 aircraft. With this mobility, it could go to the target satellite, rather than waiting for the satellite to be in a correct orbital position to be intercepted from a ground launch site. The MHV would destroy its target by direct impact, rather than carrying any explosive material.

The U.S. MHV ASAT system encountered stiff congressional opposition in the 1980s, and Congress placed limits on testing the system against objects in space until and unless the Soviets again tested their co-orbital system. Five U.S. tests were conducted: four (two in 1984 and two in 1986) against points in space; one (in 1985) against an object (an old U.S. satellite). In early 1988, DOD canceled this program because of the congressional opposition.

Other Antisatellite Devices

Ground-based lasers apparently are under development by both the United States and the Soviet Union for ASAT purposes. The Pentagon asserts that the Soviets have at least one and possibly two ground based laser sites with the potential for damaging some components of U.S. satellites. In 1987, DOD initiated a ground-based laser ASAT program of its own which will build on

activities conducted under the Strategic Defense Initiative (SDI) program. Ground-based lasers by themselves suffer two basic limitations as ASAT devices: they can only attack satellites as they pass nearly overhead, and atmospheric absorption decreases the intensity of the laser beam even in clear weather. The use of orbiting mirrors could provide more flexibility in targeting the laser beam, and very powerful lasers could mitigate atmospheric affects, however.

DOD lists other potential Soviet ASAT devices as direct ascent missiles (the Galosh antiballistic missile), electromagnetic interference (jamming), space-based directed energy (laser or particle beam) weapons, and space-based kinetic energy weapons.

The major U.S. ASAT effort today is development of ground-based kinetic energy weapons. The Army has been assigned the lead role in this program, and may use technology derived from the Strategic Defense Initiative ("Star Wars") program. DOD has stated that it wants a system to meet the "minimal" requirements established by the Joint Chiefs of Staff. (For more information, see CRS Issue Brief 85176, *ASATs: Antisatellite Weapons Systems*.)

Soviet Fractional Orbital Bombardment System (FOBS)

Although no country has placed nuclear weapons in orbit to date, the Soviets tested a system from 1967-1971 called a Fractional Orbital Bombardment System (FOBS) which could be considered such a device if it had become operational. FOBS was essentially a long range ICBM which would have approached the United States from around the South Pole, rather than the North Pole, thus avoiding the Ballistic Missile Early Warning System (BMEWS) radars which point to the north. The tests were not technically a treaty violation because there is no reason to assume they carried nuclear material, and the dummy warhead flew less than one full orbit. The system apparently has since been dismantled.

CONCERNS ABOUT THE MILITARIZATION OF SPACE AND "STAR WARS"

In the early 1980s, concern began to grow about the apparent "militarization" of space, that is, the increasing use of space for military purposes, particularly weapons. As noted above, the 1978-79 negotiations initiated by President Carter to ban weapons from space were unsuccessful. In 1981, the Soviets introduced a draft treaty at the United Nations, but a close reading showed that it would ban only the stationing of weapons in space, and since neither the co-orbital Soviet ASAT nor the U.S. MHV ASAT device was to be stationed in space, the treaty would have had little impact. No negotiations were held on this text.

In March 1983, President Reagan made a nationally televised address in which he called for research into technologies that could defend the United States and its allies against ballistic missile attacks. His advisers stated that

these systems could be based on the ground, or in space, leading the media to dub this the "Star Wars" speech. Concern about the militarization of space intensified following the President's address, and the initiation of testing of the U.S. MHV ASAT system.

In August 1983, the Soviets introduced a revised draft treaty at the U.N. which would ban the use of force in space, a much broader scope than the earlier draft, thereby prohibiting both ASAT and ballistic missile defense activities in orbit, although space-based BMD is already banned by the 1972 ABM Treaty.

During 1984, the potential for U.S./Soviet negotiations on space weapons dominated the headlines for many months, but it was not until 1985 that bilateral arms control talks resumed in Geneva on intermediate nuclear forces (INF) and strategic arms reduction (START). Space weapons were added as a third aspect of the discussions at that time. An INF agreement was signed by President Reagan and General Secretary Gorbachev in December 1987, while the START and space defense talks continue; in May 1991, the START agreement was very close to being completed.

The SDI program is very controversial in Congress, which routinely gives DOD less money than it requests for the program. For more information, see CRS Issue Brief 85170, *The Strategic Defense Initiative: Issues for Congress*, and CRS Issue Brief 88033, *The Strategic Defense Initiative: Issues for Phase 1 Deployment*.

CHAPTER 6

SPACE PROGRAM MANAGEMENT AND RESOURCES

A country's ability to routinely place satellites in orbit depends on supporting resources within that country. Among the most frequently asked questions in this regard are how much the United States and Soviet Union spend on space activities, how the respective programs are managed, and how they compare with respect to launch sites and launch vehicles.

SPACE EXPENDITURES OF THE U.S. AND U.S.S.R.

The United States spent about \$326.8 billion on the space program in the several agencies of Government involved (NASA, Departments of Defense, Energy, Commerce, Interior, and Agriculture, the National Science Foundation, and the Environmental Protection Agency) from FY1959 to FY1990 (current dollars unadjusted for inflation; the NASA figures also include non-space research, such as aeronautics, at approximately \$0.5-1 billion per year). Estimates for FY1991 funding are as follows: NASA, \$13.9 billion; DOD, \$20.4 billion; DOE, \$106.2 million; DOC, \$210.5 million; Interior, \$24 million; USDA, \$27.4 million; NSF, 0; and EPA, \$1 million.

The Soviet Union published space funding figures for the first time in 1989; no additional figures for total space program funding were published for 1990. According to the Soviets, in 1989 they spent \$11 billion per year on space: \$6.24 billion for military space programs, \$2 billion for the *Energiya/Buran* system, and the rest (\$2.76 billion) for other non-military space activities. For years, Western experts had estimated that the Soviets spent about one and a half times as much as the United States on space, or approximately \$45 billion. The large disparity between the Western estimate and the Soviet figure has left considerable doubt about what the Soviet number represents. For example, it might cover only research and development, but not procurement and operations. As a total figure for annual Soviet space funding, \$11 billion is not considered credible in the West.

MANAGEMENT OF SPACE PROGRAMS

Under the terms of the National Aeronautics and Space Act (NASAct) of 1958, the United States has separate military and civilian space programs. Civilian research and development activities are under the jurisdiction of the National Aeronautics and Space Administration (NASA), while the Department of Defense (DOD) conducts military space activities. The Department of Transportation and the Department of Commerce were given substantial roles in civilian space activities during the 1970s and 1980s. Within DOD, U.S. Space

Command in Colorado Springs, Colorado coordinates the operational aspects of space activities by all services; each service also has a separate Space Command. Several other government agencies, including the Departments of Energy, Agriculture, Interior, and State also are involved in U.S. space programs and policy. NASA and DOD together represent more than 95 percent of the U.S. space program budget.

The National Aeronautics and Space Council, a coordinating body in the Executive Office of the President, was created in the NASA Act to coordinate space policy on a Government-wide basis. It was abolished by President Nixon in 1973. President Reagan created a Senior Interagency Group/Space (SIG/Space) to coordinate U.S. space activities during his Administration, which reported to the National Security Council. Congress felt that SIG/Space was ineffective in setting space policy and, in the FY1989 NASA Authorization Bill (P.L. 100-685), recreated the Space Council, but without the aeronautics component. The new National Space Council, like its predecessor, is chaired by the Vice President.

The Soviet space program was operated almost entirely by the Strategic Rocket Forces until 1985 when a "civilian" space agency called Glavcosmos was created. The Strategic Rocket Forces are still responsible for actually launching spacecraft and almost certainly retain responsibility for planning and carrying out military space activities. During the late 1980s, Glavcosmos was described by the Soviets as responsible for building spacecraft and operating them once they are in orbit (including the *Mir* space station), as well as for commercial and international agreements.

In 1990 and early 1991, however, the role of Glavcosmos became less clear. Other organizations, especially the Energiya NPO (which designed the Energiya launch vehicle), appear to have been given or taken on a strong role in commercial space. Energiya NPO, for example, is now the agency through which foreign countries and companies negotiate agreements for launching cosmonauts to *Mir*, and it is actively working to market the Energiya launch vehicle and its components. Currently the Soviets are attempting to sell a wide variety of space products and services, including remote sensing data, launch vehicle services, opportunities to fly materials processing payloads either on free-flying spacecraft or on the Soviet space station *Mir*, opportunities to fly astronauts to *Mir*, use of Soviet communications satellites, and space nuclear reactors. One criticism made by Western customers trying to deal with the Soviets on a commercial basis is that it is not clear which organization is really in charge.

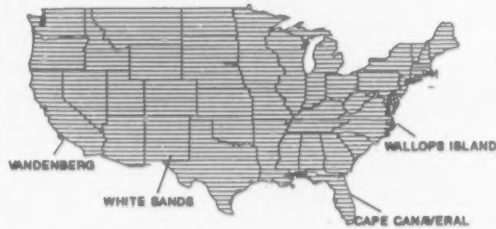
The Soviet Academy of Sciences and its institutes (especially the Institute for Space Research--IKI) historically have been responsible for building the scientific experiments for Soviet spacecraft, and planning the Soviet space science program for planetary exploration and astronomical research, for example. The Academy's Intercosmos Council for years was responsible for scientific space cooperation with other countries, although today it apparently

oversees only the development of international experiments, while agreements with other countries for scientific missions are negotiated by Glavcosmos.

LAUNCH SITES

The United States has its major launch site at Cape Canaveral, Florida (28.5°N, 80°W) for piloted, lunar, and planetary launches, and for launching satellites to geostationary orbit. It has a second launch site at Vandenberg Air Force Base, California (35°N, 121°W) for satellites which must go into polar orbits (primarily weather, remote sensing, navigation, and reconnaissance). A third minor site for small payloads is at Wallops Island, Virginia (38°N, 76°W), although it has not been used for orbital launches for years. Suborbital sounding rockets are launched from Wallops, as well as from White Sands, New Mexico, although orbital launches are not conducted there.

EXISTING US LAUNCH SITES ORBITAL AND SUBORBITAL



The Soviet Union also has three launch sites divided into basically the same functions as those in the United States. The major site for piloted, lunar, planetary, and geostationary satellites is near Tyuratam (45.6°N, 63.4°E). The Soviets call it the Baikonur Cosmodrome, but it is about 370 kilometers from the town of Baikonur. A second, largely military site is near Plesetsk (62.8°N, 40.1°E) in the Arctic. The third site is located near Kapustin Yar (48.4°N, 45.8°E) from which sounding rockets and small orbital payloads are launched. Like Wallops Island, Kapustin Yar has not been used for orbital launches for several years.

USSR LAUNCH SITES ORBITAL AND SUBORBITAL

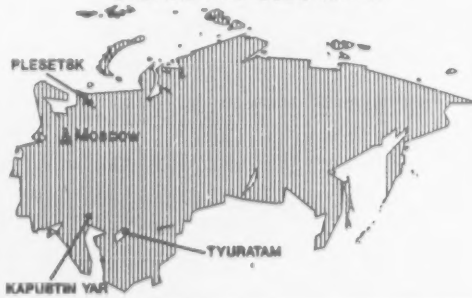


Table 5 summarizes the number of launch successes from all launch sites in the world. Woomera and Hammaguir (used by the French for early launches of the Diamant booster) have been inactive for many years; Kourou, now the site of launches using the Ariane launch vehicle, also was used previously by the

French for Diamant. The Indian Ocean Platform is used infrequently by Italy for launches using U.S. rockets. The other launch sites are discussed in part 2 of this report.

TABLE 5. World-Wide Successful Space Launches By Site

Launch Site	1990	1957-1989	Total
Plesetsk (U.S.S.R.)	48	1,247	1,295
Tyuratam (U.S.S.R.)	27	850	877
Vandenberg AFB (U.S.)	3	483	486
Cape Canaveral (U.S.)	23	394	417
Kapustin Yar (U.S.S.R.)	0	83	83
Kourou (French Guiana)	5	36	41
Tanegashima (Japan)	2	20	22
Wallops Island (U.S.)	0	19	19
Uchinoura (Japan)	1	18	19
Shuang Cheng-tzu (China)	1	17	18
Indian Ocean Platform (Kenya)	0	9	9
Xichang (China)	3	5	8
Hammaguir (Algeria)	0	4	4
Sriharikota (India)	0	3	3
Woomera (Australia)	0	2	2
Taiyuan (China)	1	1	2
Yavne (Israel)	1	1	2
Edwards AFB (U.S.)*	1	0	1
Total	116	3,192	3,308

* Departure point for aircraft used to launch satellite (the Pegasus program).

Prepared by CRS.

LAUNCH VEHICLES

The United States has used launch vehicles scaled to lift payloads from as light as 9 kilograms (Vanguard) up to the Saturn V which could carry over 136,000 kilograms to low Earth orbit.

The United States currently has the following families of "expendable" launch vehicle (ELVs), which can only be used once: Scout, Delta, Atlas, and

Titan. The only operational reusable launch vehicle in the world is the U.S. space shuttle. Scout is the smallest of the U.S. ELVs and is generally used for small scientific satellites and navigation satellites (Transit). The Delta launch vehicles are used primarily for communications, weather, or navigation satellites (NAVSTAR). Atlas launches are used primarily for geostationary communications satellites today. In the early 1960s, the Atlas was used to launch Mercury spacecraft and in the past was used for a variety of military missions. The Titan family includes a wide variety of launch capabilities. The Gemini spacecraft in the 1960s were launched with Titan IIs, which are also ballistic missiles. DOD is now reconfiguring some of the Titan IIs that are no longer needed in the ballistic missile program for use as space launch vehicles. Titan 34D and Titan IV are other current versions of the Titan, used primarily for military satellites.

The U.S. launch failures in 1986 (first the space shuttle, then a Titan and then a Delta) led to a complete reassessment of U.S. launch vehicle strategy. Originally, it had been anticipated that the space shuttle would replace Delta, Atlas and Titan and plans were underway to phase out those launch vehicles. The Air Force decided in 1984 that it wanted at least one other route to space than the shuttle, and initiated development of the Titan IV (the first was launched in 1989). Following the 1986 failures, the Government decided to adopt the Air Force philosophy of a "mixed fleet" approach in order to have assured access to space by diversifying its launch fleet. Subsequently, the Air Force contracted for a new "medium lift" vehicle, a new version of the Delta, designated Delta II. It was first launched in 1989, too. Since 1983, the U.S. Government has sought to foster the emergence of a commercial launch services market. Presidents Reagan and Bush each issued commercial launch policies, and Congress passed the Commercial Space Launch Act (P.L. 98-575) in 1984. When it procured the Delta II and Atlas II, the Air Force stipulated that they should be designed with commercial uses in mind. Today, the manufacturers of each U.S. ELV is marketing launch services (Scout-LTV Aerospace; Delta-McDonnell Douglas; Atlas-General Dynamics; and Titan-Martin Marietta). Part of the change in U.S. launch vehicle policy after *Challenger* was that NASA can no longer offer commercial launch services on the space shuttle unless the payload requires the unique capabilities of the shuttle or there are overriding foreign policy considerations. Several entrepreneurial firms are trying to build new commercial launch vehicles too, including Orbital Sciences Corporation (OSC). OSC's air-launched Pegasus launch vehicle made its first test launch in 1990. Issues involved in U.S. space launch systems are discussed in CRS Issue Brief 86121, *Space Launch Options*.

DOD and NASA have been designing an Advanced Launch System (ALS) for the post-2000 time frame to produce a new family of launch vehicles including a version capable of placing heavy payloads into orbit for substantially less cost than current vehicles. Originally, the goal of the program was to reduce the cost per pound of payload by a factor of 10; in 1989, the Air Force conceded that a factor of 3-5 was more likely. Lack of strong mission requirements for a heavy lift vehicle, however, complicated the ALS program and DOD reduced its support, issuing a stop-work order on the vehicle in December 1989.

Developmental work continues on engines, an area that is primarily the responsibility of NASA. DOD and NASA are now assessing specifications for a "New" or "National" Launch System (NLS) in response to recommendations in the Augustine Committee report (see *Introduction*). The NLS has effectively replaced the ALS program. The goal continues to be development of a new family of launch vehicles, including a "heavy lift" launch capability (67,500 kilograms--150,000 pounds--to low Earth orbit), which will reduce costs of placing satellites in orbit and be more resilient than existing launch vehicles.

NASA has been interested in an automated variant of the space shuttle, called Shuttle-C, in which the orbiter would be replaced by a cargo canister. The program has not been approved, and the NLS may incorporate some shuttle technology. In addition, DOD and NASA have begun a research program to develop "aerospace plane" technologies which could ultimately be used for military and commercial aircraft and space launch vehicles (see part 1, chapter 2).

Like the United States, the Soviet Union has a variety of different launch vehicles capable of lifting different size payloads into orbit. The Soviet vehicles have several designations in the West. Some refer to them with SS numbers, others with SL numbers, and still others with NATO names. Charles Sheldon, the late Congressional Research Service specialist who originated this series of reports, developed his own alpha-numeric system which is also widely used. This system designates the vehicles with the letters A, B, C, D, F, J and K in the order in which they entered service for space launches. Upper stages are designated e, h and m. Numbers differentiate various combinations of stages. Thus, there may be D-1 launches, or D-1-e if a particular type of upper stage is added; F-1-m or F-2 vehicles, again depending on the particular configuration. Details of this designation system can be found in the *Soviet Space Program* reports prepared by CRS and published by the Senate Commerce, Science and Transportation Committee. The nomenclature system became more confused in 1986 and 1987 when the Soviets began offering their launch vehicles on a commercial basis and for the first time publicly gave names to them. In this report, the Sheldon system will be used together with the Soviet names.

The A-1 (Vostok) and A-2 (Soyuz) vehicles have been used throughout the history of the Soviet space program for launches related to the piloted program (both for carrying crews into orbit and related cargo flights), as well as for many other missions, particularly photographic reconnaissance satellites. In its A-2-e (Molniya) form, it is used for Molniya communications satellites and early warning satellites. The "B" launch vehicle series is no longer used. The "C" (Cosmos) is the smallest in the fleet and is used for science, navigation and minor military launches. The "D" (Proton) launch vehicle is used for space stations, geostationary satellites, the GLONASS navigation satellites, and planetary and other large science spacecraft. The "F" (Cyclone) is used for launches of ocean reconnaissance satellites and was used for the co-orbital ASAT program. It is also used for weather and remote sensing satellites. The "G" (N-1) designation was used for the Saturn V-class vehicle the Soviets attempted to develop in the late 1960s for their lunar program.

In 1985, flights began of a new medium lift vehicle called Zenit and designated J in the Sheldon system. Zenit was launched several times in 1986-1988, but not at all in 1989, and only once successfully in 1990. There was also a Zenit failure in 1990; it exploded on the launch pad.

Zenit is the launch vehicle the Cape York Space Agency (CYSA) would like to use for commercial launches from Australia. The Soviets want to enter the international commercial launch services market, but U.S. policy prohibits the export of any satellite containing U.S. components to the Soviet Union because of technology transfer concerns. The United States also is concerned that the Soviets, with their non-market economy, might unfairly compete with U.S. companies by offering launch vehicle services at very low prices. CYSA, a private Australian company, has proposed building a launch site at Cape York, Australia, from which they would launch Zenit rockets purchased from the Soviet Union. The rockets would be owned by CYSA, and satellites would be integrated onto the rockets by Australians or Americans (a U.S. company, U.S. Space Boosters Inc.--USBI, part of United Technologies--has shown interest in managing the launch site). Australian officials assert that no Soviets need to be at the launch site at all. If these arrangements were to satisfy technology transfer concerns, the issue of how much CYSA would charge per launch, and if fair trade practices were followed, would remain. Prompted in part by a request from USBI for a license to work with CYSA on this proposal, the Bush Administration issued a commercial space launch policy in September 1990 specifying, among other things, what agreements would have to be made among the Australians, Soviets, CYSA, USBI and the United States Government for this project to proceed. The Soviets have rejected one of the provisions (that they conduct commercial launches from only one site outside the Soviet Union and not from within the Soviet Union). Also, CYSA's parent company, Essington Developments, is experiencing financial difficulties and is seeking to sell CYSA so the future of the project is in doubt. (See CRS Issue Brief 86121, *Space Launch Options*, for further information.)

In May 1987, the Soviets conducted a test of another new vehicle, designated K in the Sheldon system and named Energiya by the Soviets. It is similar in capability to the Saturn V. The payload did not reach orbit, however, so the test was a partial failure. Energiya was used to launch the Soviet space shuttle in 1988, and has not been launched since. Energiya consists of a central core, fueled by liquid hydrogen and liquid oxygen, the first Soviet launch vehicle to use this dual cryogenic fuel combination. Four Zenit boosters are used as strap-ons (Zenit uses kerosene and liquid oxygen for fuel), and the Soviets have indicated that more strap-ons can be added if additional lift capability is required. No portion of the Energiya is reusable, although the Soviets are looking at whether or not to recover the strap-ons in the future.

Table 6 summarizes worldwide use of basic vehicles for successful launches to Earth orbit and beyond. It should be remembered that a "successful" launch simply means that the payload reached orbit, not whether it achieved the intended orbit.

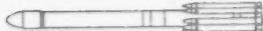
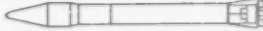
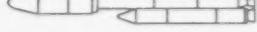
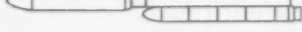
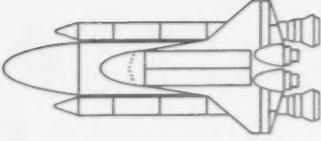
TABLE 6. Worldwide Successful Launches by Basic First Stage

Name	Country	1990	1957-1989	Total
Soyuz/Vostok/Molniya (A)	USSR	42	1,248	1,290
Delta	USA	11	391	402
Cosmos (C)	USSR	10	363	373
Cyclone (F)	USSR	12	253	265
Atlas	USA	3	209	212
Proton (D)	USSR	10	160	170
Titan	USA	5	156	161
(B)	USSR	0	144	144
Scout	USA	1	82	83
Space Shuttle	USA	6	31	37
Ariane	ESA	5	30	35
Long March	China	5	23	28
Mu	Japan	1	17	18
N	Japan	0	15	15
Saturn V	USA	0	13	13
Saturn I	USA	0	13	13
Zenit (J)	USSR	1	11	12
Diamant	France	0	10	10
H	Japan	2	5	7
Redstone	USA	0	4	4
Jupiter	USA	0	4	4
Vanguard	USA	0	3	3
SLV-3	India	0	3	3
Shavit	Israel	1	1	2
Lambda	Japan	0	1	1
Black Arrow	U.K.	0	1	1
Energiya (K)	USSR	0	1	1
Pegasus	U.S.	1	0	1
Total		116	3,192	3,308

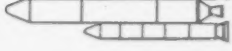
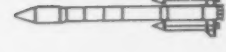
Prepared by CRS. New analysis may alter totals for individual launch vehicles from year to year.

Primary Launch Vehicles of the World

U.S. launch vehicles

							
Scout	Delta	Delta 2	Atlas 1	Atlas 2	Titan 3	Titan 4	Shuttle
LEO 475 lbs.	7,800 lbs.	11,000 lbs.	12,000 lbs.	14,500 lbs.	32,500 lbs.	39,000 lbs.	52,000 lbs.
GTO NA	3,500 lbs.	4,000 lbs.	5,200 lbs.	6,000 lbs.	12,500 lbs.	12,000 lbs.	NA

Foreign launch vehicles

									
Vostok (SL-3)	Soyuz (SL-4)	Proton (SL-12/13)	Energia (SL-17)	Energia (SL-17)	Ariane 3	Ariane 4	Ariane 5	Long March 2E	H-2
LEO 11,000 lbs.	17,000 lbs.	43,000 lbs.	220,000 lbs.	66,000 lbs.	NA	14,000 lbs.	44,000 lbs.	19,000 lbs.	18,000 lbs.
GTO NA	NA	8,000 lbs.	NA	NA	7,000 lbs.	9,000 lbs.	15,000 lbs.	7,000 lbs.	9,000 lbs.

KEY: GTO = Geostationary Transfer Orbit; LEO = Low Earth Orbit
 SOURCE: Office of Technology Assessment, 1990.

CHAPTER 7

FUTURE DIRECTIONS

Attempting to predict the future of the U.S. space program is a difficult assignment as it depends upon political decisions as much as on technical capabilities, both of which are virtually impossible to foretell. There are more engineering possibilities than there are financial resources likely to be made available to pursue them.

Estimating what the Soviet Union will elect to do in space is difficult, too, for all those reasons plus trying to peer through their veil of secrecy, which is thinner because of *glasnost*, but still prevents a true understanding of their program. The Soviets have stated very long-term goals (such as colonizing other planets), but have not elaborated on time frames, and the new political and budgetary climate there will complicate their planning activities.

Nevertheless, it seems useful to identify some of the possibilities facing both countries in the longer term future.

THE NATIONAL COMMISSION ON SPACE AND RIDE REPORTS

In 1986 and 1987, two reports were published relating to long-term goals for the U.S. civilian space program. The first, *Pioneering the Space Frontier*, was prepared by a specially appointed commission and looked out to the year 2035. The second, *Leadership and America's Future in Space* (or the "Ride Report" after its chief author, astronaut Sally Ride), focussed on four selected program areas through the early part of the 21st Century.

Pioneering the Space Frontier

In 1984, Congress decided that it was time to appoint an outside panel to look at the long-term future of the U.S. civilian space program. Language in NASA's FY85 authorization bill directed President Reagan to establish a National Commission on Space, with 15 members, to spend one year developing recommendations on where the space shuttle and space station programs should lead the United States. The legislation specified that the Commission take as givens both of those programs, and that military space activities not be addressed.

President Reagan officially established the Commission in October 1984, but did not name the 15 commissioners until March 1985. Chaired by former NASA Administrator Thomas O. Paine, the Commissioners spent one year assessing what the country wanted its space program to do, and making

recommendations about how to satisfy those needs. Fifteen public forums were held across the United States to solicit input from citizens; monthly meetings were held at which experts could testify to the Commission on their ideas about future space programs; and letters were sent to a wide variety of well-known individuals (in and outside of the space community) in the United States asking for their input as well.

From this and their own expertise, the Commissioners developed a 50-year plan for the United States detailed in their report *Pioneering the Space Frontier*. In summary, the Commission called for the United States to lead the way in opening the inner solar system for science, exploration, and development. In doing so, the Commission envisioned establishment of bases on the Moon and Mars, and creation of a routine transportation system among the Earth, Moon and Mars. The Commissioners emphasized that they were not trying to predict the future, but rather to show what the United States could do if it so chose.

One area which the Commissioners felt was of critical importance was developing low cost access to space. They concluded that in order to reduce cost, separate vehicles should be developed for taking people and cargo into space, unlike the space shuttle which was designed for both. For cargo transport, they recommended that the private sector be closely involved in developing the next generation launch vehicle so that it can be operated by the private sector rather than the Government. They left open the question of whether it should be derived from existing technology or completely new. For transporting people (and high value cargo) they concluded that aerospace plane technologies (see part 1, chapter 2) and advanced rocket technologies should be developed over a five year period, after which a decision could be made as to which was the better approach.

Once these vehicles are available, a "Highway to Space" would be established, permitting routine, low-cost access to Earth orbit and the Moon (using transfer vehicles from Earth orbit). The Commission envisioned people returning to the Moon by 2005 and establishing first outposts, and later settlements from which they could mine lunar resources and conduct scientific experiments (astronomers, for example, are anxious to place observatories on the far side of the Moon where they will be shielded from the interference created by humans on Earth).

To reach Mars, which the Commissioners suggested for the year 2015, a "Bridge between Worlds" would be created. The Commissioners believed that an approach different from the Apollo program should be used when sending people to Mars. Instead of going for a short time, collecting samples, and returning home, the Commissioners recommended routine access to Mars, which, like the Moon, would be a site for science, exploration, and resource development. Thus, the Commissioners envisioned two cycling spaceships on interlacing, repetitive trajectories between the Earth and Mars. Travel time to and from Mars would be approximately six months, and stay time on Mars could be as long as a year.

The report detailed a program involving both piloted and automated activities, acting synergistically to achieve the goal of opening the inner solar system. Throughout the process, the Commission envisioned the private sector following the Government and taking over operation of space facilities, for example, and making lucrative businesses out of resource operations. Although the Commission recognized that the Government would have to pave the way, it fully expected the private sector to follow. The Commission also expressed the hope that its recommendations would galvanize the most creative minds throughout the world to accomplish the goals in the report. Thus, they recommended that the United States lead the way in this area; not necessarily do it alone.

Leadership and America's Future in Space

Unlike the Commission's report, Sally Ride's *Leadership and America's Future in Space* was prepared as an internal NASA report. Dr. Ride spent approximately a year looking at four program areas for comparatively near-term (15-20 year) activities: Mission to Planet Earth, automated exploration of the solar system, a lunar outpost, and sending humans to Mars. Her report recommends that NASA pursue programs in each of these areas.

Mission to Planet Earth is the name given to a program designed to better understand Earth, the forces that act on it, how those forces interact, and what that means to the population living here. The program envisions considerable international cooperation, including satellites from many different countries, contributing to its scientific activities.

Solar system exploration would focus on three automated space science programs: the Mars rover/sample return mission designed to return samples of Martian soil; Cassini, for studying Saturn and its moon Titan; and the Comet Rendezvous/Asteroid Flyby (CRAF) mission for studying these "primitive" bodies.

The lunar outpost would involve establishing a permanent scientific facility on the Moon and to begin prospecting the Moon's resources. The Ride report envisioned humans returning to the Moon in the year 2000, preceded by automated probes to select a site for the outpost.

Concerning human exploration of Mars, Dr. Ride's group looked at what has come to be called "sprint" missions to Mars wherein crews go the planet on three quick round trips, in the same vein as the Apollo trips to the Moon. The missions, between 2005 and 2010, would each take one-year (round-trip), with crews exploring the surface for approximately two weeks. Subsequently, a commitment to a permanent Mars base could be made. She concluded that this approach was not ideal considering the scope of the activity compared with NASA's budget constraints, and that a "Mars Race" should be avoided. She concluded that "Settling Mars should be our eventual goal, but it should not be our next goal" (page 54).

As a result of the Ride report, NASA established an Office of Exploration to investigate long-range proposals for sending humans back to the Moon or to Mars. The office published a report on its progress in 1988 entitled *Beyond Earth's Boundaries*. In early 1990, the Office of Exploration was merged with NASA's Office of Aeronautics and Space Technology to form the Office of Aeronautics, Exploration and Technology. Mission to Planet Earth has now been made part of NASA's FY91 budget request (see part 1, chapter 3), and CRAF and Cassini were initiated in FY90 (see part 1, chapter 4).

PRESIDENT BUSH'S "SPACE EXPLORATION INITIATIVE"

On July 20, 1989, the 20th anniversary of the first Apollo landing on the Moon, President Bush made a major space policy address, endorsing the goal of returning humans to the Moon and then going on to Mars "in the 21st Century." He also restated his support for the space station *Freedom* program, and for Mission to Planet Earth. Some view the President's speech as an endorsement of the National Commission on Space and Ride reports.

While the President's speech provided concrete goals for the space program, some Members of Congress criticized it for not having a specific timetable or cost estimates. The President assigned the task of developing a schedule and budget to the National Space Council. The Space Council continues to review options for meeting the President's goal of sending humans to the Moon and Mars, now named the "Space Exploration Initiative" (SEI). The SEI is controversial for several reasons. First is its expected cost. OMB Director Richard Darman has stated that it will cost \$400 billion over 30 years, although actually there is no cost estimate for the program since decisions have not been made on how it would be accomplished. Second, there are critics who argue that human exploration of the solar system is unnecessary and too risky, preferring robotic spacecraft for such activities. A third aspect of the controversy is whether humans should return to the Moon before going to Mars, or simply proceed on to Mars since we already have been to the Moon. These issues are discussed in more detail in CRS Issue Brief 90112, *The Moon/Mars Proposal: President Bush's Space Exploration Initiative*.

The Space Council established "the Synthesis Group" to seek out innovative approaches ("mission architectures") for accomplishing SEI from the American public, industry, and Government agencies (including NASA, DOD and the Department of Energy). Often called the Stafford Group after its chairman, former astronaut Lt. Gen. (Ret.) Thomas Stafford, it is expected to issue a report in the summer of 1991 outlining four potential mission architectures for the program. The Space Council also is discussing the possibility of international cooperation in SEI on a conceptual basis with Canada, European countries, and the Soviet Union. SEI has not received strong support in Congress because of budget constraints, so it is not clear how quickly the program will move forward. The Augustine Committee recommended that this activity be placed in a separate program office at NASA headquarters as it was after the release of the Ride Report, and that it have responsibility for related missions, such as robotic missions to explore Mars. NASA Administrator Truly has announced that he

will recreate the Office of Exploration, although the scope of its responsibilities have not yet been determined.

LONG-TERM SOVIET PLANS

Although few Soviet comments were made about human missions to the Moon during the 1970s and early 1980s, there have been several references in recent years to the advantages of a lunar base. Soviet scientist Vladislav Shevchenko published an article in late 1986, for example, discoursing upon the mineral prospecting that could be done on the Moon and suggesting a scenario and time frame (2007) for creating a permanent lunar base. Late in 1987, General Vladimir Shatalov, chief of cosmonaut training, noted that it might be necessary to have crews spend up to a month on the Moon to begin readapting to gravity after a trip to Mars (although Mars itself has more gravity than the Moon, the interplanetary journey would probably be in zero-g). Once *Energiya* is operational, the Soviets could decide to send crews to the Moon at any time. Budgetary constraints make such a program seem unlikely in the near future, however.

It is apparent both from Soviet statements and their space station missions that Mars is their ultimate goal. They frequently state that one of the reasons they are extending the duration of piloted missions in Earth orbit is to obtain data on human reaction to spaceflight conditions so someday they can send crews to Mars. After the 237-day flight in 1984, TASS directly tied that duration to the length of time it would take to send a crew to Mars.² This theme was reiterated in December 1987 at the end of the 326-day flight of Yuriy Romanenko.

There are many hurdles to overcome before crews can be sent to Mars. Although Romanenko appeared to be in very good health after his 11 months in orbit, and Titov and Manarov after their year-long stay, there is much to be understood about human reaction to long durations in weightlessness and the isolation of a spacecraft both physiologically and psychologically. For example, Romanenko admitted after eight months in orbit that he constantly felt fatigued and was not sleeping well. By the end of the mission, his work day had been cut to 4-4.5 hours.

Interplanetary flights also pose health problems not encountered in Earth orbit--particularly exposure to galactic cosmic rays, for which no effective shielding has yet been developed. Other problems will include logistical support for a crew enroute to Mars. The Soviet space station crews are frequently resupplied by cargo ships bringing food, water, equipment, repair parts, etc. Whatever supplies are needed for the Mars voyage will have to be taken with the crew (or sent on ahead). The Soviets are experimenting with techniques to create closed cycle life support systems for recycling air, water, food and waste products, but these are far from being practicable (they have had great difficulty, for example, in getting plants to go from seed, to maturity, to seed again). If closed cycle systems are not available, the logistical requirements for supporting even a small crew would be considerable.

The current state of the Soviet economy makes forecasts about future Soviet space plans especially difficult. Even plans for a follow-on to the *Mir* space station (*Mir 2*) apparently have been deferred or canceled, making it unlikely that the Soviets will make a major commitment to a program of human exploration of the Moon or Mars anytime soon.

COOPERATION BETWEEN THE UNITED STATES AND SOVIET UNION

The United States and Soviet Union have had cooperative agreements almost since the beginning of the space program, but most have been for data exchange on scientific missions. The most far-reaching agreement was signed in 1972 and provided for the Apollo-Soyuz Test Project described in chapter 2. A follow-on agreement, signed in 1977, laid the groundwork for establishment of the international satellite search and rescue system, COSPAS-SARSAT, described in chapter 3, and for cooperation on Soviet flights involving animals.

When the 1977 agreement expired in 1982, President Reagan refused to renew it because of strained relations between the two countries following the imposition of martial law in Poland. The 1983 Soviet destruction of Korean Airlines 007 further distanced the countries and space cooperation waned.

In June 1984, President Reagan invited the Soviets to participate in a joint spaceflight that would involve a simulated mission between the U.S. space shuttle and the Soviet *Salyut* space station to demonstrate the ability of each side to rescue the other's space crews. At this time, however, the Soviets began linking cooperation in space with cancellation of the U.S. Strategic Defense Initiative (SDI). In the summer of 1986, however, the Soviets suddenly decoupled the two issues, and in April 1987, U.S. Secretary of State George Shultz and Soviet Foreign Minister Shevardnadze signed an agreement calling for cooperation in data exchange from planetary missions and biomedical experiments. This was expanded somewhat during the May-June 1988 summit between President Reagan and General Secretary Gorbachev.

Today, the most active discussion surrounds the potential of joint U.S./Soviet missions to Mars--first the automated rover/sample return mission described in chapter 4, and later, sending joint crews to Mars. Some supporters of a joint human mission to Mars see it as an alternative to SDI. This view was first publicly expressed by astronomer Carl Sagan at 1984 hearings by the Senate Foreign Relations Committee on a resolution introduced by Senator Matsunaga. The resolution (S. J. Res. 236) was enacted into law (P.L. 98-562), but called primarily for a resumption of the U.S./Soviet agreement for space cooperation in general, not specifically Mars.

In 1987, Congressman Robert Roe, then Chairman of the House Science, Space and Technology Committee, and Congressman Manuel Lujan, then ranking minority member of that committee, wrote to President Reagan asking that he raise the possibility of a joint mission with Soviet General Secretary Gorbachev at their December 1987 summit. Although President Reagan

apparently did not raise the issue, Gorbachev did, at least indirectly. After signing the Intermediate Nuclear Forces (INF) treaty, Gorbachev stated that "people want to live in a world in which American and Soviet spacecraft would come together for docking and joint voyages, not for 'Star Wars.'" Dr. Roald Sagdeyev, then head of the Soviet Institute for Space Research, published an editorial in the Washington Post (December 13, 1987) in which he clarified that Gorbachev meant voyages to Mars. Although the Soviets have not formally proposed a date for sending crews to Mars, Sagdeyev allowed that his "sentimental" choice would be 2001, while conceding that 2005 would be more realistic.

Some Western observers regret the linkage between SDI and a joint Mars mission for fear that if SDI is canceled, the Mars mission would lose impetus. Others are not sanguine about the possibility of the superpowers maintaining steady relations for a long enough period of time to complete such a mission. It might take ten years to plan and several more to carry out. There has been no period of time since World War II when U.S./Soviet relations have been stable for so long. For this reason, some supporters of missions to Mars suggest that the United States conduct the project with its allies, rather than the Soviet Union, while others suggest that it be a multilateral endeavor including the United States, Soviet Union, Europe, Japan and possibly other countries. The dramatic changes now occurring in the Soviet Union (and Eastern Europe) make predictions about future superpower relationships especially difficult. As noted earlier, the National Space Council is discussing the possibility of international cooperation in the Space Exploration Initiative with the Soviets (among others), but only on a conceptual basis.

There is also the potential problem of technology transfer. If the two countries are to mount the entire mission jointly, it would be virtually impossible not to share technology. One possible solution would be for the countries to have coordinated missions that go at the same time, but on different spacecraft. Another solution is simply to accept that technology transfer will occur. The attractiveness of the latter option will be dependent on how the superpowers view each other at the time joint human missions to Mars are actually being designed, which, as noted, is virtually impossible to forecast today.

CHAPTER 8

TABLE OF SPACE 'FIRSTS'--U.S. AND SOVIET

Any attempt to compare the relative pace of the two principal space programs through a table of "firsts" has certain weaknesses, as it does not answer by how many days or years a particular event occurred in one country before another. Further, it does not distinguish between a nominal first accomplishment in crude form by one country, sometimes followed by a much more impressive and elaborate follow-up by the other country. Nonetheless, such firsts do affect public opinion, and analysis by various fields of endeavor may give some sense of relative direction of pacing efforts in each country. Table 7 attempts such a measure.

TABLE 7. Major U.S. and Soviet Space "Firsts"

United States		
Event	Satellite	Launch Date
Biological and Piloted Flight		
Piloted orbital maneuver	Gemini 3	03/23/65
Controlled extravehicular activity	Gemini 4	06/03/65
Piloted space rendezvous	Gemini 6, 7	12/04/65
Piloted docking with automated vehicle	Gemini 8-Agena	03/16/66
Piloted lunar orbit	Apollo 8	12/21/68
Piloted lunar return reentry	Apollo 8	12/21/68
Lunar orbit rendezvous	Apollo 10	05/18/69
Lunar landing and return	Apollo 11	07/16/69
Piloted lunar rover	Apollo 15	07/26/71
International docking	Apollo	07/15/75
Flight of reusable vehicle	STS 1	04/12/81
4-person crew	STS 5	11/11/82
5-person crew	STS 7	06/18/83
6-person crew	STS 9	11/28/83
Untethered EVA	STS 41-B	02/03/84
In-orbit satellite repair	STS 41-C	04/06/84
7-person crew	STS 41-G	10/05/84
Satellite retrieval/return	STS 51-A	11/08/84
8-person crew	STS 61-A	10/30/85
Science*		
Van Allen radiation belts	Explorer 1	02/01/58
Earth shape measured	Vanguard 1	03/17/58
Orbiting solar observatory	OSO 1	03/07/62
Data from Venus	Mariner 2	08/27/62
Geodetic satellite	Anna 1B	10/31/62
Lunar close-up pictures	Ranger 7	07/28/64
Mars pictures	Mariner 4	11/28/64
Micrometeorite satellite	Pegasus 1	02/16/65
Lunar orbit pictures	Orbiter 1	08/10/65
Lunar trenching	Surveyor 3	04/17/67
Lunar soil chemical analysis	Surveyor 5	09/08/67
Live lunar TV broadcast	Apollo 8	12/21/68
Return of lunar rocks	Apollo 11	07/16/69
Color pictures of Jupiter	Pioneer 10	03/03/72
Color pictures of Saturn	Pioneer 11	04/06/73
Radiotelescope in lunar orbit	Explorer 49	06/10/73
Pictures of Venus	Mariner 10	11/03/73
Pictures of Mercury	Mariner 10	11/03/73
Solar Probe	Helios 1	12/10/74
Mars surface pictures	Viking 1	08/22/75
High energy astronomy observatory	HEAO 1	08/12/77
Pictures of Jupiter and its Moons	Voyager 1	09/05/77
Pictures of Saturn and its Moons	Voyager 1	09/05/77
Pictures of Uranus and its Moons	Voyager 2	08/20/77
Pictures of Neptune and its Moons	Voyager 2	08/20/77
Comet intercept (Giacobini-Zinner)	ICE	08/12/78

TABLE 7. Major U.S. and Soviet Space "Firsts"--continued

Union of Soviet Socialist Republics		
Event	Satellite	Launch Date
Biological and Piloted Flight		
Animal in space (dog)	Sputnik 2	11/03/57
Animal in space, recovered	Korabl	08/19/60
	Sputnik 2	
Man in space, recovered	Vostok 1	04/12/61
Woman in Space, recovered	Vostok 6	06/16/63
Multi-crew spacecraft	Voskhod 1	10/12/64
Extravehicular activity	Voskhod 2	03/18/65
Recovery, circumlunar live animals	Zond 5	09/21/68
Docking between piloted spacecraft	Soyuz 4/5	01/14/69
Space station	Salyut 1	04/19/71
International docking	Soyuz 19	07/15/75
2 ferry craft docked to station	Soyuz 26/27	01/10/78
International crew launch	Soyuz 28	03/02/78
Construction in space	Soyuz T-9	06/27/83
Woman EVA	Soyuz T-12	07/17/84
Crew Rotation	Soyuz T-13/T-14	09/00/85
Ferry between space stations	Soyuz T-15	03/13/86
Science*		
Orbiting geophysical lab	Sputnik 3	05/15/58
Farside lunar picture	Luna 3	10/04/59
Cosmic ray measurements	Proton 1	07/16/65
Pictures from lunar surface	Luna 9	01/31/66
Lunar surface bearing test	Luna 13	12/21/66
Venus atmospheric probe	Venera 4	06/12/66
Automated return of lunar sample	Luna 16	09/12/70
Automated lunar roving laboratory	Luna 17	11/10/70
Venus soil analysis	Venera 8	03/27/72
Venus surface pictures	Venera 9	06/08/75
Radio telescope 10-meter dish	Salyut 6	09/29/77

*This table shows launch dates rather than the date of the event described. This is particularly important to remember with the science missions, since the event may occur years after launch. For example, Voyager 2 was launched in 1977, but encountered Uranus in 1986 and Neptune in 1989.

TABLE 7. Major U.S. and Soviet Space "Firsts"—continued

United States		
Event	Satellite	Launch Date
Civil and Military Applications		
Active communications	Score	12/18/58
TV pictures from space	Explorer 6	08/07/59
Weather satellite	Tiros 1	04/01/60
Navigation satellite	Transit 1B	04/13/60
Missile detection	Midas 2	05/24/60
Observation recoverable flight	Discoverer 13	08/10/60
Passive communications	Echo 1	08/12/60
Operational synchronous communications	Syncom II	07/26/63
Nuclear explosion detection	Vela Hotel	10/17/63
Earth resources satellite	ERTS 1	07/23/72
Synchronous 24-hour weather	SMS 1	05/17/74
Commercial maritime communications	Marisat 1	02/19/76
Ocean resources satellite	SeaSat 1	06/27/78
Space Flight and Propulsion		
Multiple spacecraft payload	Transit/Solrad	06/22/60
Payload recovery	Discoverer 13	08/10/60
Hydrogen rocket orbited	Centaur 2	11/27/63
Docked spacecraft maneuver	Gemini 10-Agenda	07/18/66
Lunar-velocity reentry	Apollo 4	11/09/67
Constant deceleration reentry	Apollo 8	12/21/68
Mars orbit	Mariner 9	05/30/71
Jupiter flyby	Pioneer 10	03/03/72
Solar system escape	Pioneer 10	03/03/72
Venus/Mercury flyby	Pioneer 10	03/03/72
Jupiter/Saturn flyby	Pioneer 11	04/05/73
Uranus/Neptune flyby	Voyager 2	08/20/77
Libration point halo orbit	ISEE 3	08/12/78
Auxiliary Power Systems		
Solar cells	Vanguard 1	03/17/58
Isotope power	Transit 4A	06/29/61
Nuclear reactor in orbit	Snapshot 1	04/03/65
Fuel cell	Gemini 5	08/21/65

TABLE 7. Major U.S. and Soviet Space "Firsts"—continued

Union of Soviet Socialist Republics		
Event	Satellite	Launch Date
Civil and Military Applications		
Domestic communications	Molniya 1-1	04/23/65
Fractional orbit bombardment	Cosmos 139	01/25/67
Co-orbital antisatellite test	Cosmos 248-249	10/20/68
Radar ocean surveillance	Cosmos 626?	12/29/73
Space Flight and Propulsion		
Space flight	Sputnik 1	10/04/57
Earth escape spacecraft	Luna 1	01/02/59
Lunar impact	Luna 2	09/12/59
Orbital platform launch	Sputnik 5	02/21/61
Venus flyby	Venera 1	01/12/61
Mars flyby	Mars 1	11/02/62
Venus impact	Venera 3	11/16/65
Lunar soft landing	Luna 9	01/31/66
Lunar orbiter	Luna 10	03/31/66
Automatic docking	Cosmos 186/188	10/27-29/67
Recovery, lunar payload	Zond 5	09/21/68
Skip reentry lunar payload	Zond 6	11/10/68
Venus soft landing	Venera 7	07/17/70
Mars impact	Mars 2	05/19/71
Mars soft landing	Mars 3	05/28/71
Venus orbit	Venera 9	06/18/75
Automatic propellant transfer	Progress 1	01/20/78
Auxiliary Power Systems		
Battery power	Sputnik 1	10/04/57
Gallium arsenide solar panel addition	Salyut 7	04/19/82

Prepared by CRS.

PART TWO

SPACE ACTIVITIES OF OTHER LAUNCHING COUNTRIES/ORGANIZATIONS

For the first two decades of the space program, the United States and Soviet Union clearly dominated space activities. While they still are responsible for the vast majority of space launches today, the 1980s witnessed the emergence of five additional launching countries/organizations: China, the European Space Agency (ESA, a group of 13 European nations), India, Israel, and Japan.

Four other countries--Australia, France, Italy, and the United Kingdom--are sometimes counted as launcher countries, but are not included here. Australia and Italy have both operated launch facilities. Australia launched its own satellite, Wresat, from Woomera in 1967. Since a U.S. rocket was used for the launch and no other Australian launches have been made, it is not counted here as a launcher country. Italy's facility (the San Marco Platform off the coast of Kenya) is still used occasionally, and Italy has launched five of its own satellites, but these also have used U.S. launch vehicles, so Italy is not counted as a launching country.

France and the United Kingdom did develop their own launch vehicles. The French Diamant successfully placed 12 payloads in orbit from 1965 to 1975, but was then phased out of service. At first, the French launched from Hammaguir, Algeria. In 1970, they transferred operations to the Kourou facility in South America, used today by ESA and Arianespace. The British Black Arrow successfully placed one satellite (Prospero) in orbit in 1971 from Woomera, Australia, but the rocket was never used again for space launches. Since their indigenous launch vehicles are no longer in use, neither country is included here as a separate launching country, although both are now members of ESA.

In 1989, Iraq launched a missile that it stated was a space launch vehicle, but no satellite was placed in orbit. The launch vehicle is designated Al-Abid. In the wake of the Persian Gulf War, it seems extremely unlikely that Iraq will be pursuing a space program in the near future; if it does develop a satellite and launches it into orbit, Iraq will be added.

CHAPTER 1

CHINA

China launched its first satellite in 1970. By the end of 1990, it had made a total of 28 launches, successfully placing 31 satellites into orbit. The Chinese have not announced the missions for many of the satellites launched in the 1970s and early 1980s. Several of these were recovered on Earth after a few days in space, suggesting that they returned film images of the Earth (either for military reconnaissance or civilian land remote sensing purposes). Others were not recovered and their missions remain unclear. They could have been related to scientific research or to a different type of reconnaissance capability which does not require the spacecraft to be returned (electronic intelligence, for example). A few launches, including one in 1981 which placed three spacecraft into orbit simultaneously, definitely have been for scientific research. Others have placed communications satellites in orbit. China has conducted three commercial launches since 1987: two carried materials processing payloads (for a French company and a German consortium, respectively), and the third was a communications satellite (for Asiasat Inc.).

Most Chinese launches have taken place from Shuang Cheng-tzu (41.7°N, 100.1°E) in the northern part of China (near Jiuquan). The Long March 2 (CZ 2) rocket is used at this site. In 1984, the Chinese introduced the Long March 3 (CZ 3) launch vehicle, which has a cryogenic (liquid oxygen/liquid hydrogen) upper stage. The vehicle inaugurated use of a new launch site at Xichang (28°N, 103°E) in southeastern China. The first launch of the Long March 3 did not put the payload in the correct orbit and is counted in this report as a launch success, but a payload failure. Several more successful launches of the Long March 3 have followed, placing communications satellites in geostationary orbit. In 1988, the Chinese launched their first weather satellite using a new version of their rocket, Long March 4, and a new launch site, Taiyuan (38°N, 112°E). The satellite was placed into a polar orbit and apparently failed soon after launch. Another was launched in 1990.

The Chinese have not revealed how much they spend on their space program.



DEVELOPMENT OF THE CHINESE SPACE PROGRAM

The history of the Chinese space program officially is still shrouded in secrecy, but occasionally information is released by the government. For example, the Chinese announced in 1984 that they had flown a puppy into space on a suborbital rocket in 1967. The puppy, named Xiao Bao (Little Leopard), was successfully recovered. They also reported that there had been a major explosion at one of their launch pads on January 28, 1978, which resulted in at least seven people being seriously injured, and a dozen or more people receiving burns to their hair, eyebrows, and faces. In addition, they honored as a martyr a young engineer who helped develop the first geostationary satellite, but died after 6 or 7 years of suffering the health effects of exposure to radiation during experiments related to that task.

An article in the May 1991 issue of *Space Policy* by Yanping Chen sheds some light on the development of the Chinese space program, concluding that despite a constantly changing political and economic climate, the space program has remained relatively stable. Dr. Chen, a visiting scholar at George Washington University in Washington, D.C., divides the program into four distinct periods: 1956-1966, when the space program was first established despite a number of "traumatic political events" including the Great Leap Forward and the withdrawal of Soviet support for Chinese science and technology; 1966-76, during which the space program was able to maintain its course even though "virtually all sectors of Chinese society were torn apart" by the Cultural Revolution; 1976-1986, a period when the space program was put on the back burner, but survived, while the country recovered from the Cultural Revolution; and 1986 to today, which Dr. Chen describes as the "heyday" of the program as the government has made space a "cornerstone of the national science and technology development effort."

COMMERCIAL LAUNCH SERVICES

Since 1986, the Chinese have been actively marketing launch services using the Long March family of vehicles through the China Great Wall Industry Corporation. As noted earlier, the first commercial launches were of materials processing experiments using the Long March 2, first for a French company (Matra) in 1987 and then for a German consortium (Intospace) in 1988.

The market for commercial communications satellites is larger than for materials processing experiments, and China has focussed great attention on attempting to get contracts for these launches. Virtually all commercial communications satellites are made by U.S. companies or contain U.S. components, so export licenses from the United States are required for the satellites to reach China for launch.

In 1988, the first such export license requests were made to the U.S. State Department for two Australian satellites, AUSSAT 1 and 2, being built by Hughes Aircraft, and one satellite named Asiasat-1, which is the refurbished Westar 6 satellite (also built by Hughes) recovered by a space shuttle crew in

1984 after it failed to achieve the proper orbit. Asiasat Inc., which bought Asiasat-1, is a company owned by three entities, each having a one-third share: Cable and Wireless PLC of London, Hutchinson Telecommunications Ltd. of Hong Kong, and CITIC Technology Inc., a subsidiary of China's International Trust and Investment Corp. Cable and Wireless has overall management responsibility for Asiasat; the company is based in Hong Kong.

In September 1988, the Reagan Administration conditionally approved export of the three satellites to China. The conditions were that China sign three international treaties concerning, among other things, liability for damage from space launches; that China negotiate a fair trade agreement with the United States regarding launch services; and that agreement be reached on protecting technology while each satellite is in China. All these conditions were met by January 1989. Two of the conditions to which China agreed was that it would seek to launch no more than nine international satellites between 1989 and 1994, and that it would charge prices "on a par" with other launch services providers.

Approval for the export of the AUSSAT and Asiasat-1 satellites was granted by CoCom, the Coordinating Committee on Multilateral Export Controls, whose members are all the NATO countries (except Iceland), Japan and Australia. Following the Tiananmen Square uprising in June 1989, however, the Bush Administration suspended all export licenses for items on the Munitions Control List, including the three satellites. Congress passed legislation, the FY1990 Commerce, Justice, State and Judiciary appropriations (P.L. 101-162), prohibiting export of the satellites unless conditions improved in China, or unless the President certified to Congress that it was in the national interest of the United States to reinstate the licenses. In December 1989, the President made that certification to Congress; Asiasat-1 was launched by China in April 1990. The AUSSAT satellites are still under construction in California, with both launches anticipated in 1992. Their original export licenses expired in March 1991, but the Bush Administration renewed them. In 1990, China tested a new version of the Long March 2 (called the 2E) which is needed for the AUSSAT launches; the Chinese reported that it did not place its primary payload (a "dummy" AUSSAT satellite) into the proper orbit, although a secondary payload (a Pakistani test satellite) did achieve the correct orbit.

The future for Chinese launch services is uncertain. The United States is concerned about Chinese policies in several areas--human rights and political freedom, proliferation of ballistic missile technology, and adherence to the 1989 U.S.-China agreement on launch services--and may use the issuance of export licenses as leverage to influence Chinese actions.

As noted above, Congressional concern about internal Chinese policies on human rights and political freedom was expressed in P.L. 101-162, and although that Act expired at the end of fiscal year 1990, similar language is included in the 1990-1991 Foreign Relations Authorization Act (P.L. 101-246) which is in force until September 30, 1991.

The issue of whether China is adhering to its agreement with the United States to charge fair prices for launch services was raised most recently by a 1990 contract between China and the Arabsat Consortium for launching an Arabsat satellite for \$25 million, much less than what many consider "on a par" with Western companies. The main competitor for the launch was Europe's Arianespace, which turned to both the French and U.S. governments to prohibit export of the satellite (the prime contractor for the satellite is French, and it includes American components). The United States took no formal action and the issue became moot in the spring of 1991 when the Arabsat Consortium terminated the contract with the Chinese and signed an agreement with Arianespace. The reasons have not been fully explained by any of the parties, and the issue of what constitutes pricing services "on a par" remains, since it is not specified in the U.S.-Chinese agreement. Language prohibiting the export of satellites to China unless the President certifies that China is complying with the 1989 agreement was included in the Export Facilitation Act of 1990 (H.R. 4653). That bill was vetoed by President Bush on November 17, 1990, but a similar bill (S. 320) passed the Senate on February 20, 1991 and includes the same language. China argues that because their costs are so low, they can offer lower prices and still adhere to international norms as to what costs are included in setting the price.

Although the Bush Administration renewed the export licenses for the two AUSSAT satellites in the spring of 1991, and approved the export of components for a Swedish satellite (Freja) to be launched by China, it denied approval for exporting components China wanted for building a new communications satellite. That denial was based on Bush Administration concern about China exporting ballistic missiles to other countries.

In the spring of 1991, Indonesia chose an American company (McDonnell Douglas) to launch its Palapa satellite instead of selecting China, apparently in part because of the uncertainty surrounding U.S. export policy regarding satellites to be launched by China. Other potential customers may make the same decision, leaving China's commercial launch services future in doubt.

OTHER DOMESTIC AND INTERNATIONAL SPACE ACTIVITIES

The Chinese are interested in land remote sensing satellites. They inaugurated use of a Landsat receiving station purchased from the United States in 1986, which may also be able to receive data from the French SPOT satellite. As discussed earlier, several Chinese satellites reportedly have been related to development of a remote sensing capability, including one of the satellites launched in 1990 (China 33, which also carried a biological experiment). Presumably, this involves using a film system (rather than scanners such as those on Landsat and SPOT), hence the need for the payload to be recovered. China undoubtedly is interested in remote sensing both for military and civilian purposes.

Some Chinese satellites have been for scientific purposes. As noted, China 33 (which was recovered) carried a biological payload--more than 60 plants and animals (guinea pigs). Two balloons for making atmospheric measurements were launched along with China's second weather satellite, Feng Yun 1-2, in 1990. In 1981, China launched three small satellites simultaneously for atmospheric physics studies. The two commercial launches that carried foreign materials processing experiments also carried Chinese materials processing experiments.

China has had cooperative space agreements, primarily for general scientific and technical cooperation, with several countries, including Germany, Italy, France, and Australia. China's most extensive international cooperative project is with Brazil to jointly build two remote sensing satellites, CBERS-1 and -2 (China-Brazil Earth Resources Satellite). Despite a number of problems in the program since its official initiation in 1988, it apparently is going forward for a planned first launch in 1993. Most recently, Brazil wanted to increase its share of the work in building the satellites, but China objected. According to Brazilian sources, China asserted that it was not confident that Brazil's National Institute of Space Research (INPE) was capable of accomplishing complex technical tasks, but INPE officials believe China is concerned about technology transfer. Originally, they were to have been launched on Brazilian launch vehicles, developed with Chinese assistance. The satellites now apparently will be launched by China, although Brazil states that it has not signed a launch agreement with China yet. China is paying 70 percent of the project's cost (\$150 million, including launch). Also, China Great Wall Industry Corp. and Brazil's Avibras Aeroespacial signed a joint venture agreement in 1989 to create a company (INSCOM) specializing in satellite launches, tracking and networking.

As noted earlier, China launched an experimental Pakistani amateur radio satellite in 1990. The satellite, Badr-1, failed after one month in orbit.

There is no U.S./Chinese cooperative space agreement, although the Chinese have indicated that they would like to fly an astronaut on the space shuttle, and in 1986 selected two student experiments for the shuttle. The two countries have discussed a draft space cooperation agreement for several years, but it has never been completed.

FUTURE PLANS

It is extremely difficult to discuss the future of the Chinese space program, not only because they do not release very much information about their activities, but also because their plans change quite abruptly. During 1979 and 1980, they expressed great plans for utilization of space, and even had astronauts in training. In late 1980 and early 1981, however, they retreated from their expansive plans because of a reassessment of the Chinese economic situation, and announced that their piloted space program had been postponed for at least the remainder of the decade. Today, they talk boldly about building space stations and a space shuttle, although economic conditions in China make

it unlikely that they would do so before the year 2000, despite reports in the late 1980s that they once again were training astronauts.

TABLE 8. Chinese Space Launches

Name	Launch Date	Launch Site	Comments
China 1	04/24/70	S	Engineering test. "East is Red" song played until 05/20/70.
China 2	03/03/71	S	Housekeeping test and possible science.
China 3	07/26/75	S	Science? Reconnaissance? Not recovered.
China 4	11/26/75	S	Possible reconnaissance test. Recovered.
China 5	12/16/75	S	Like China 3.
China 6	08/30/76	S	Possible electronics intelligence gathering test and/or science. Not recovered.
China 7	12/07/76	S	Possible reconnaissance test. Recovered.
China 8	01/26/78	S	Possible reconnaissance test. Recovered.
China 9-11	09/19/81	S	Triple scientific payload for space physics experiments.
China 12	09/09/82	S	Possible reconnaissance test. Recovered.
China 13	08/19/83	S	Possible reconnaissance test. Recovered.
China 14	01/29/84	X	First Long March 3 launch; upper stage failed.
China 15	04/08/84	X	First Chinese geostationary communications satellite.
China 16	09/12/84	S	Reconnaissance? Remote sensing? Recovered.

TABLE 8. Chinese Space Launches
(continued)

Name	Launch Date	Launch Site	Comments
China 17	10/20/85	S	Reconnaissance? Remote sensing? Recovered.
China 18	02/01/86	X	Communications.
China 19	10/06/86	S	Possible reconnaissance. Recovered.
China 20	08/05/87	S	Materials processing experiment for a French company.
China 21	09/09/87	S	Science. Recovered.
China 22	03/07/88	X	Communications
China 23	08/05/88	S	Materials processing for German company.
China 24	09/06/88	T	Weather.
(Feng Yun 1-1)			
China 25	12/22/88	X	Communications.
China 26	02/04/90	X	Communications.
Asiasat 1	04/07/90	X	Communications satellite for Asiasat Co. First Chinese commercial satellite launch.
BADR-1; China 29	07/16/90	X	Pakistani test communication satellite, plus "dummy" AUSSAT satellite. China 29 did not achieve proper orbit.
Feng Yun 1-2;	09/03/90	T	Weather satellite, plus two balloons for atmospheric studies.
China 31;			
China 32			
China 33	10/05/90	S	Earth resources and biology. Recovered.

S = Shuang Cheng-tzu. X = Xichang. T = Taiyuan. Launch dates are in Greenwich Mean Time.

Prepared by CRS based on data from Chinese news bulletins; *World-Wide Space Activities* (House Science and Technology Committee, 1977); and Clark, P. S. The Chinese Space Programme. *Journal of the British Interplanetary Society*, v. 37, 1984. p. 195-206.

CHAPTER 2

EUROPEAN SPACE AGENCY AND ARIANESPACE

The European Space Agency (ESA) was formed in 1975 by the merger of the European Scientific Research Organization and the European Launcher Development Organization, each of which had been created in 1964. Today, ESA has thirteen members (Austria, Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom), and a technical agreement of cooperation with Canada as well. ESA's activities are all civilian; it is prohibited by its charter from conducting military space programs. Its 1990 budget (January-December 1990) was \$2.2 billion.

A major ESA activity has been development of an independent launch capability using a launch vehicle called Ariane. France played the lead role in developing Ariane, and the vehicle is launched from Kourou (5.2°N, 52°W) in French Guiana (South America). In addition, Arianespace, a private company which now markets Ariane and manages the launches, is incorporated in France. As a result, Ariane is often mistakenly referred to as a French launch vehicle.

Arianespace, as noted above, is now responsible for operational Ariane launches so it, rather than ESA, is the "launching organization" included here. ESA continues to develop new versions of Ariane, and is responsible for test launches. Its activities will continue to be included in this report. Several ESA members (notably France, Italy and West Germany) have their own strong indigenous space programs, but the nature of this report does not permit extensive discussion of them.

ARIANE AND ARIANESPACE

The French space agency, CNES, is a major shareholder in Arianespace (32 percent); the other shareholders are 51 European companies and banks. Arianespace is the main competitor to U.S. launch services companies, and reportedly has garnered more than 50 percent of the market. Ariane enjoys a reputation for being quite reliable despite its 5 failures in 40 launch attempts (an 87.5 percent success rate). The most recent failure was in February 1990, when the



vehicle exploded shortly after launch, destroying the two Japanese broadcasting satellites it was carrying. A small rag had been left in a water supply line to one of the first stage engines, causing the engine to lose pressure. Launches were interrupted for five months, but customers were signing contracts with Arianespace just weeks after the failure and before the cause was determined. The Ariane 4 is the only version of Ariane currently available. Earlier models (Ariane 1, 2 and 3) have been phased out of usage.

The United States and ESA are engaged in negotiations over "rules of the road" for offering commercial space launch services to ensure that everyone follows similar practices for determining prices to be offered. The negotiators are looking both at U.S. and European practices in "subsidizing" launch services, and at issues involved in the entry of countries with non-market economies (China and the Soviet Union) into the market. The talks formally began in September 1990 and are expected to continue through 1991.

ARIANE 5, COLUMBUS AND HERMES: ESA'S MAJOR INITIATIVES FOR THE 1990s

ESA divides its activities into two categories: mandatory activities to which all members must contribute, and voluntary activities, where member countries choose whether or not to participate. The mandatory activities involve primarily space science and applications programs (see below).

The three major voluntary space programs today are development of a new version of Ariane (Ariane 5), ESA's contributions to the U.S./International Space Station *Freedom* program (Columbus), and a reusable vehicle for taking crews back and forth to space (Hermes). The three activities are closely linked.

Ariane 5 will be capable of placing 15,000 kilograms into low Earth orbit or 4,500 kilograms into geostationary orbit. All the ESA member countries except the United Kingdom are participating in this program. Among its main uses will be launching the Hermes spaceplane, although apparently a separate version of Ariane 5 will have to be developed to provide the safety, reliability, and lift capability needed for Hermes, which has grown in weight over its original specifications. All the ESA member countries except Ireland and the United Kingdom participate in the Hermes program; Canada is also a participant.

A primary use for Hermes, designed to carry three astronauts, is to support Columbus, Europe's contribution to the Space Station *Freedom* program. The Columbus program has three components: the Columbus pressurized laboratory module that will be attached to *Freedom* (see part 1, chapter 2 for more information on *Freedom*); the Columbus Free-Flying Laboratory (CFFL) which will be placed in a separate orbit apart from *Freedom* for experiments that cannot be conducted on the space station itself; and the Columbus Polar Platform that will be placed in polar orbit for earth observations (part of the Mission to Planet Earth program--see part 1, chapter 3). Nine of the 13 ESA members are participating in the Columbus program (Belgium, Denmark,

France, Germany, Italy, the Netherlands, Norway, Spain, and the United Kingdom). Hermes is being designed to take crews to the pressurized module and to service the CFFL.

The ESA Council approved funding for the first phase (definition and development) of the three programs in 1987, but must approve the second phase (full scale development and production) in late 1991. The total cost of the three programs from 1987 to the year 2000 is estimated at \$47 billion. As discussed below, financial strains on some of the ESA member countries and cost growth in the programs may lead to deferral, downscoping, or possibly cancellation of some of them. For example, there is considerable discussion about reducing the size of the Columbus attached pressurized module (the United States reduced the size of its two modules in 1991), and divorcing the CFFL (formerly called the Man-Tended Free Flyer) from the rest of the space station program, making its design less complex. Under this plan, the CFFL would be serviced only by Hermes, instead of being compatible with the space station. Changes in the Hermes program are also being discussed, delaying the first flight from 1998 to late in the year 2000, and with only one (instead of two) flights per year during the development phase. Hermes costs and weight have grown; it is too heavy for the Ariane 5 now under development so a new version, designated Ariane 5 Plus, will be proposed to the ESA ministers. Apparently these costs will be attributed to the Ariane 5 program, not Hermes.

SPACE SCIENCE AND APPLICATIONS

ESA conducts a broad program of space science and applications missions. Among its most notable space science achievements so far is Giotto, a spacecraft sent to Halley's Comet in 1985. The probe was the only one of the five Halley's Comet probes (two Soviet, two Japanese and one European) to enter the nucleus of the comet. Giotto may be targeted to intercept another comet, Grigg-Skjellerup, in 1992.

In 1990, ESA's Ulysses spacecraft was launched by the United States. Its task is to study the polar regions of the Sun, and is enroute to Jupiter first to receive a gravity assist from the giant planet to swing it out of the plane of the ecliptic (in which the planets lie) so it can achieve a polar orbit around the Sun. As noted below, the Ulysses program at one time was to consist of two spacecraft, one U.S. and one European, for simultaneous observations of both poles of the Sun, but the United States abrogated the agreement to provide its spacecraft in 1981. It did maintain its commitment to launch and track the European spacecraft, and to provide its electrical power source.

ESA is now participating with the United States in the Cassini mission to send a two-part spacecraft to Saturn in 1996. One portion will orbit the planet, while the other will descend through the atmosphere of Titan, one of Saturn's moons (and the only moon in the solar system surrounded by an atmosphere). The Titan probe, called Huygens, is being built by ESA.

ESA also has built earth-orbiting scientific probes, such as Hipparchos, an astronomical observatory launched in 1989. Although it was placed into an improper orbit, scientists are receiving usable data from. ESA also contributed one of the main instruments for NASA's Hubble Space Telescope (the Faint Object Camera), and now is building the Infrared Space Observatory for launch in 1993.

ESA's long-term space science program is called Horizon 2000 and has four cornerstones: two probes, Cluster and SOHO, as part of the International-Solar Terrestrial Physics program; another comet mission, called the Rosetta Comet-Nucleus Sample-Return Mission, to return samples from the nucleus of a comet; the X-ray Multi-mirror Mission (XMM) for X-ray astronomy; and the Far-Infrared and Submillimetre Space Telescope (FIRST).

Space applications also are a significant focus of ESA activities. In 1991, ESA will launch a remote sensing satellite carrying a synthetic aperture radar called ERS-1. ESA also has developed geostationary weather satellites (Meteosat) and communications satellites. These are operated by quasi-governmental organizations (Eumetsat and Eutelsat, respectively). ESA also plans to participate in the Mission to Planet Earth (see part 1, chapter 4) program using the Columbus Polar Platform for environmental observations.

ESA has conducted some microgravity materials processing experiments so far (although France and Germany are quite involved in this area of research through their national space programs), and expects to accelerate its activities once the Eureka platform is available. Eureka (European Retrievable Carrier) platforms were built as a follow-on to the Spacelab pallet (see below), and will serve as a structure (or "bus") for providing power supply and orbit stabilization systems for experiments which can be placed on and later removed from it. Eureka platforms will be deployed from and retrieved by the U.S. space shuttle, and can accommodate 1,000 kilograms of payload.

Development of new communications satellites, including data relay satellites, are also on ESA's agenda. ESA launched its most recent communications satellite, Olympus, in 1989 and it was designed to operate for five years. In May 1991, however, the satellite began spinning uncontrollably and operators are not certain they can salvage the mission; an investigation team has been formed.

COOPERATION WITH THE UNITED STATES AND SOVIET UNION

ESA's programs have involved a considerable degree of cooperation with the United States. Overall, the cooperation has been useful and positive for both sides. One example of successful cooperation was the development of the Spacelab module which flies in the cargo bay of the space shuttle, providing a "shirt-sleeve" environment for performing a wide variety of experiments. Spacelab was developed as a cooperative project with NASA during the 1970s, with West Germany as the lead country. Spacelab pallets were also developed

by ESA for use outside the habitable module for those experiments which require exposure to the space environment. The first Spacelab module, provided free to NASA as part of the cooperative agreement, was delivered in December 1981, and was launched in November 1983. The crew included an ESA astronaut, Ulf Merbold of West Germany, the first non-American to fly on an American piloted mission. NASA purchased a second Spacelab module, an option provided for in the agreement. European industry had hoped NASA would buy additional Spacelabs, but fiscal constraints and a reduced shuttle launch rate precluded such a purchase.

ESA-NASA cooperation has not been trouble-free. The most often cited difficulty occurred in 1981 when the United States canceled plans to build a spacecraft as part of the International Solar Polar Mission (ISPM). Originally, ISPM would have involved the launch of two probes to simultaneously study the North and South poles of the Sun. ESA and NASA would each have provided one spacecraft, and NASA would have supplied the power unit (a radioisotope thermal generator), launch, and tracking for both probes. In 1981, President Reagan abrogated the memorandum of understanding with ESA on ISPM because of fiscal constraints, prompting formal statements of displeasure from several ESA member countries to the U.S. State Department. Nevertheless, the mission could not be accommodated within NASA's budget, and the U.S. spacecraft was canceled. NASA maintained its commitment to provide the power unit, launch, and tracking. Renamed *Ulysses*, it was launched in October 1990.

Relations between NASA and ESA cooled slightly because of the ISPM incident, but the two agencies continue to develop programs jointly. As discussed earlier, for example, ESA agreed to participate in the Space Station *Freedom* program. The Columbus pressurized module builds on ESA's Spacelab experience. The constant changes in *Freedom*'s design and schedule have created tensions between NASA and ESA, but the two sides seem committed to the program. ESA is also involved in several scientific programs (such as the Cassini mission discussed above) with the United States.

Until the 1980s, ESA did not cooperate with the Soviet Union in space activities (although some individual European countries did, notably France). ESA's first cooperative activity with the Soviets was on the 1988 Phobos missions to Mars (see part 1, chapter 4). In 1990, ESA and the Soviets signed an agreement for further cooperation covering solar system exploration, space astronomy and astrophysics, solar-terrestrial physics, earth observation including meteorology and geodesy, space biology and medicine, and fundamental research in the field of microgravity. One proposed mission is a space-based radio telescope called the IVS which would integrate a 20-meter radio telescope designed by ESA onto a Soviet spacecraft. The IVS would be launched by the Soviet Energiya rocket in about 2001.

FUTURE ESA PROGRAMS

As noted, ESA is now embarked upon a sizable program for the 1990s involving a new launch vehicle, contributions to the Space Station *Freedom*

program, and a spaceplane. Several of the major ESA partners have expressed concern about ESA's commitments. Germany, in particular, struggling with the financial burden of reunification, is seeking to scale back the Columbus design, although it has said it will honor its existing commitments to ESA. Italy also has expressed concern, and Britain already has scaled back its participation in voluntary ESA activities (it is involved in only one of the three major programs--Columbus--and is interested only in the polar platform for remote sensing observations). France appears to be the only major partner not publicly expressing doubts about the magnitude of the ESA program. Hence, it seems unlikely that ESA will commit itself to new, major programs while Ariane 5, Columbus and Hermes are in development.

Europe has made no secret of its strong desire for autonomy in space. Ariane was the first step towards independence, and once Hermes is available, Europe no longer will be dependent on the United States (or the Soviet Union) for launches of crews into space, either. Considering its long history of international cooperation (ESA itself is an international entity, after all), ESA can be expected to continue to play a strong role in international space efforts even after it achieves autonomy, however.

TABLE 9. European Space Agency/Arianespace Launches

Name	Launch Date	Comments
CAT	12/23/79	Success. First test launch. Carried CAT test package.
Firewheel; Oscar 9	05/23/80	Failure. Second test launch. One scientific and one communications satellite lost.
Meteosat; Apple	06/19/81	Success. Third test launch. Launched European weather satellite and experimental Indian satellite.
Marecs	12/20/81	Success. Fourth and final test launch.
Marecs B; Sirio 2	09/09/82	Failure. First operational launch. Two communications satellites lost.
ECS; Oscar 10	06/16/83	Success. Placed two communications satellites in orbit.
Intelsat	10/19/83	Success. Communications satellite.
Intelsat	03/05/84	Success. Communications satellite.
GTE Spacenet	05/22/84	Success. Communications satellite. First launch operations by Arianespace.
ECS-2; Telecom 1A	08/04/84	Success. Two communications satellites.
GTE Spacenet; Marecs B2	11/09/84	Success. Two communications satellites.
Arabsat; Brazilsat	02/08/85	Success. Two communications satellites.
GSTAR-1; Telecom 1B	05/08/85	Success. Two communications satellites.
Giotto	07/02/85	Success. Halley's Comet probe.
GTE Spacenet; ECS 3	08/12/85	Failure. Two communications satellites lost.
SPOT; Viking	02/22/86	Success. French remote sensing satellite and Swedish scientific satellite.
GSTAR III; Brazilsat	03/28/86	Success. Two communications satellites.
Intelsat	05/30/86	Failure. One communications satellite lost.
AUSSAT; ECS-4	09/15/87	Success. Two communications satellites.
TVSAT 1	11/21/87	Success. Communications satellite.
GTE Spacenet; Telecom 1C	03/11/88	Success. Two communications satellites.
Intelsat	05/17/88	Success. Communications.
Meteosat; Amsat; Panamsat	06/15/88	Success. First launch of Ariane 4. Weather, amateur radio, and communications satellites.

TABLE 9. European Space Agency/Arianespace Launches
(continued)

Name	Launch Date	Comments
Insat 1C; ECS-5	07/21/88	Success. Two communications satellites.
Gstar 3; SBS 5	09/08/88	Success, but Gstar kick motor failed. SBS communications satellite OK.
TDF 1	10/20/88	Success. Communications.
Skynet 4B;	12/11/88	Success. Two communications satellites.
ASTRA 1B		
Intelsat	01/26/89	Success. Communications satellite.
JCSAT; MOP	03/06/89	Success. JCSAT is Japanese communications satellite; MOP is European weather satellite.
Tele-X	04/01/89	Success. Swedish communications satellite.
Superbird; Kopernikus	06/05/89	Success. Superbird is Japanese communications satellite; Kopernikus is German communications satellite.
Olympus	07/11/89	Success. European communications satellite.
TV-SAT; Hipparchos	08/09/89	Success. TV-SAT is German communications satellite; Hipparchos is European astronomical satellite that was placed into an improper, but usable, orbit.
Intelsat	10/27/89	Success. Communications satellite.
SPOT 2; Pacsat; DOVE; Webersat; Lusat; UOSAT 3; UOSAT 4	01/22/90	French remote sensing satellite, plus six "microsats" for communications and science from various countries.
BS2X; Superbird B	02/22/90	Failure. Both Japanese communications satellites lost.
TDF-2; Kopernikus-2	07/24/90	Two communications satellites.
Eutelsat II F1;	08/30/90	Two communications satellites.
Skynet 4C		
SBS 6; Galaxy VI	10/12/90	Two communications satellites.
Satcom C1; GSTAR IV	11/20/90	Two communications satellites.

All launches are from Kourou, French Guiana (South America). Does not include launches conducted for Europe by other countries. Prepared by CRS.

CHAPTER 3

INDIA

India has been involved in developing satellites and launch vehicles for many years. Its first satellite, Aryabhata, was launched by the Soviet Union in 1975. While cooperation with the Soviets has continued (they launched three remote sensing satellites for the Indians--Bhaskara 1 and 2 in 1979 and 1981 respectively, and IRS in 1988), and there is extensive cooperation with the West as well, India has pursued development of an independent launching capability. The Indian Space Research Organization (ISRO) is the primary government space agency in India, and is based in Bangalore. Launches are made from Sriharikota (in the Bay of Bengal, 13°N, 80°E). India's 1988/1989 space budget (April 1988 to March 1989, the latest figure available), was \$252 million.

The first test launch of the Indian SLV-3 booster failed in August 1979. The Indians achieved success with their second test launch on July 18, 1980, however, which placed the Indian satellite Rohini 1 into Earth orbit (it remained in orbit until July 1981, longer than expected). The third SLV-3 flight took place on May 31, 1981, and although it succeeded in placing Rohini 2 into orbit, the altitude was lower than planned and the satellite decayed after only 9 days (instead of the expected 300 days). These Rohini satellites were primarily for monitoring the performance of the launch vehicle, although Rohini 2 also carried remote sensing equipment. On April 17, 1983, the Indians orbited Rohini 3 and announced it was for Earth resources studies. Some Western sources have suggested that the Indians are attempting to develop a military reconnaissance capability more than civilian remote sensing satellites. In March 1987, they tested a new Augmented Satellite Launch Vehicle (ASLV). The test flight failed, as did a second test in July 1988.



A version of the launch vehicle capable of placing satellites in polar orbits is also being developed, called the Polar Satellite Launch Vehicle (PSLV). In 1990, India asserted that it would test launch the PSLV in 1991. India is reportedly interested in receiving assistance from other countries (especially France or the Soviet Union) in developing launch vehicles, but such assistance

would be complicated by the Missile Technology Control Regime (MTCR) agreement which is designed to prevent the proliferation of ballistic missile technology. France and the Soviet Union have signed the MTCR.

The Indians developed an experimental communications satellite, APPLE, which was launched on the third Ariane test flight in June 1981. One of the solar panels did not deploy properly, but the satellite operated with reduced power for two years. Other Indian satellites (the INSAT series) have been procured commercially and have three functions: meteorology, voice and data transmissions, and direct broadcast transmissions. The first was launched in April 1982, and experienced several problems--the solar sail did not deploy at all, and the C-band antenna would not deploy for several weeks--and by September its fuel supply (which should have lasted for many years) was exhausted, apparently because an open valve allowed the fuel to escape. The back-up satellite, INSAT 1B, was launched by the space shuttle in 1983 and operated correctly. INSAT 1C was launched by an Ariane in 1988, and INSAT 1D was launched on a U.S. Delta II rocket in 1990 (its launch was delayed by a year after it was damaged during an accident on the launch pad during launch preparations and had to be returned to the manufacturer for repairs).

The INSAT program developed partially out of a cooperative program with the United States called SITE (Satellite Instructional Television Experiment). From 1975 to 1976, the United States lent its sixth Applications Technology Satellite (ATS-6) to India for use in transmitting educational programs to 5,000 remote Indian villages. The Indian government developed the programming itself and the project was considered such a success that the direct broadcast part of the INSAT series was created to continue the effort.

India is far from having its own ability to place people in space, but there has been an Indian cosmonaut. In April 1984, an Indian military pilot, Rakesh Sharma, flew into space on Soyuz T-11 with two Soviet cosmonauts and docked with the *Salyut 7* space station, which was already occupied by three other cosmonauts. Sharma remained on board the space station for seven days, participating in a variety of experiments including performing yoga to determine if special muscle relaxation techniques would help overcome the temporary physiological effects of weightlessness. The Indians also hope to send a scientist into space on a U.S. space shuttle mission.

With its push towards commercializing space activities, recent agreements with the Soviets to launch Indian satellites have been negotiated on a commercial basis; previously the Soviets conducted the launches on a cooperative basis. The first "commercial" launch was of IRS-1, for which India reportedly paid 75 million rupees (\$4.5 million), a very small price for a commercial launch. Three more agreements reportedly have been signed, but no information on prices has been revealed by either side: IRS-1B, planned for launch in 1991; IRS-1S, for launch in 1994; and an Indian communications satellite (GRAMSAT) in 1995.

TABLE 10. Indian Space Launches

Name	Launch Date	Comments
SLV 3	08/10/79	Test flight. Failure.
Rohini 1	07/18/80	Test satellite. Success.
Rohini 2	05/31/81	Test satellite. Lower orbit than planned, but satellite worked for 9 days.
Rohini 3	04/17/83	Remote sensing. Success.
ASLV	03/24/87	Test flight of new vehicle. Failure.
ASLV	07/13/88	Failure.

Does not include launches conducted for India by other countries. Prepared by CRS.



CHAPTER 4

ISRAEL

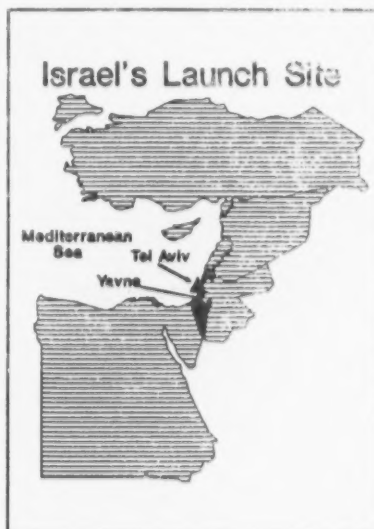
On September 19, 1988, Israel became the newest member of the family of launching countries, placing its first satellite, Ofeq 1 (Horizon 1) into orbit. To avoid flying over other countries during launch, the Israelis used a highly unusual flight path which headed northwest over the Mediterranean. This trajectory placed the satellite into a retrograde orbit (against the direction of the Earth's rotation), at an inclination of 143° . The satellite was not designed to operate for very long, and it reentered Earth's atmosphere in January 1989.

The 156 kilogram satellite was a test spacecraft, probably related to the development of a reconnaissance satellite, but useful for any type of satellite mission. U.S. and Soviet reconnaissance satellites are placed into polar orbits which allow the satellite to view any place on the globe. In this type of the orbit, the satellite's view is limited to areas 37 degrees north and south of the equator. This would give the Israelis good coverage of their Middle East neighbors, but not of the Soviet Union, for example.

A second satellite, Ofeq 2, was launched in April 1990. Similar to Ofeq 1, it was designed to test communication and control systems, and was capable of two-way communications; it reentered three months later. They have announced plans to launch a third, more advanced, satellite in 1991 or 1992, though it apparently will not be larger. Israeli officials have stated that it will weigh 160 kg and carry one or two instruments for X-ray astronomy.

The Israelis have not announced the location of their launch site, but it apparently is at Yavne (31.8°N , 34.75°E). The Israelis call their launch vehicle Shavit, and Western observers speculate that it is based on the Jericho II missile.

Israel is building a geostationary communications satellite system called Amos; the first of two satellites is planned for launch in 1994. Israel will procure commercial launches for the satellites (Arianespace reportedly is the front-runner). The Amos satellites are being constructed by Israeli Aircraft Industries Ltd. (IAI), a company wholly



owned by the Israeli government, which also built the Ofeq satellites and the Shavit launch vehicle. IAI is trying to market the Shavit for commercial launches of small payloads.

In 1990, the Israel Institute of Technology (Technion) signed a cooperative space agreement with the Soviet Union for scientific and engineering studies in X-ray astronomy and satellite, planetary exploration, instrumentation, solar-terrestrial physics, earth remote sensing, and ecological monitoring.

The Israeli Space Agency (part of the Ministry of Science and Technology)

CHAPTER 5

JAPAN

Japan has made 41 successful launches since 1970, placing 40 satellites successfully in orbit. The Japanese space program focuses on development of launch vehicles; communications, weather, remote sensing, and scientific satellites; and a module for the U.S./International Space Station *Freedom*. A 1969 resolution passed by the Japanese Diet prohibits Japan from pursuing space programs for other than peaceful purposes (there continues to be a debate within Japan as to whether that precludes all military space activities or only those for "aggressive" purposes such as space weapons).

There are two major governmental organizations involved in launching satellites in Japan: the National Space Development Agency (NASDA), a quasi-governmental organization reporting to the Ministry of Posts and Telecommunications, the Ministry of Transport, and the Science and Technology Agency; and the Institute of Space and Astronomical Science (ISAS), part of the Ministry of Education. Their activities are coordinated by the Space Activities Commission, which reports to the Prime Minister's office. Japan's total 1990 space budget (April 1990-March 1991) was \$1.2 billion.

Japan has used three families of launch vehicles. ISAS develops and operates the Mu series of launch vehicles to place its scientific satellites in Earth orbit or into deep space. Launches take place from Uchinoura (32°N, 130°E) near Kagoshima, 900 kilometers southwest of Tokyo. A new version, M-5, is now under development. For many years, NASDA used the N-1 and N-2 rockets, manufactured in Japan under license from the McDonnell-Douglas Corporation (they are based on McDonnell Douglas' Delta launch vehicle). The 1969 U.S.-Japanese agreement giving Japan access to that technology specifies that the launch vehicles can be used only for peaceful purposes, and cannot be used to launch satellites for other countries without U.S. permission. Hence, Japan began development of its own launch vehicle called the H. The first version, the H-1, has replaced the N-1 and N-2. It still uses some U.S. technology and thus is subject to the stipulations of the

JAPANESE LAUNCH SITES



1969 agreement. The H-2, which will be entirely Japanese, is under development and is expected to achieve its first launch in 1993. NASDA launches from Tanegashima (31°N, 130°E), an island south of Uchinoura.

The Japanese are limited by government agreements with fishermen near the two launch sites to launch no more than twice per year out of each site, limiting the total number of annual launches Japan can make. Japan has shown interest in offering commercial launch services once the H-2 is operational, but would probably have to renegotiate with the fishermen, or build another launch site elsewhere in the Pacific, perhaps in conjunction with other interested parties. One possibility is using the Cape York, Australia launch site being proposed by the Cape York Space Agency (discussed in part 1, chapter 6).

In 1990, 77 Japanese aerospace corporations, insurance companies and banks created a new company, Rocket Systems Inc., to build the H-2 launch vehicle. Japanese officials stated that the primary motivation behind the formation of the company was not to enter the commercial launch market, but to reduce launch vehicle costs for NASDA and spread financial risk. Officials involved in the creation of the company asserted that no decision has been made whether to offer launches on the commercial market. In the spring of 1991, however, a Mitsubishi Heavy Industries official indicated that Rocket Systems would bid on three satellite launch contracts for the mid-1990s to gain experience in the process (Mitsubishi is the main shareholder in Rocket Systems).

SPACE SCIENCE AND APPLICATIONS PROGRAMS

Japan's space activities have a strong focus on space science and applications. ISAS is responsible for the space science program, and has launched a number of earth orbiting satellites for astronomy and other research. ISAS has also launched three modest deep space probes: two (Sakigake and Suisei) investigated Halley's Comet in 1986; the third, Muses-A, was launched to the Moon. It was primarily an engineering test rather than a scientific mission. More advanced lunar missions have been proposed for the late 1990s. Japan is also building the Geotail satellite for launch by a U.S. rocket in 1992 as part of the International Solar Terrestrial Physics program (see part 1, chapter 4). Other space science projects for X-ray astronomy, radio astronomy, and solar research are underway for launches in the early- and mid-1990s.

NASDA oversees the government's role in developing applications satellites. Among them are geostationary weather satellites (the GMS series), ocean sensing satellites (Marine Observation Satellite--MOS, also called MOMO), and communications satellites. Launch of the Japan's first land remote sensing satellite (JERS-1) satellite is currently scheduled for early 1992. It will carry a synthetic aperture radar and stereo camera, among other instruments, and help explore for oil and mineral resources. Japan already is a heavy user of U.S. Landsat and French SPOT remote sensing data.

In 1995, Japan plans to launch ADEOS, the Advanced Earth Observing System, which will carry two NASA instruments along with Japanese sensors. ADEOS will provide data relevant to Mission to Planet Earth (see part 1, chapter 3), as will the Tropical Rainfall Mapping Mission (TRMM), another Japan/U.S. project, planned for launch in 1996. Japan is planning a specialized platform, JPOP (Japanese Polar Orbiting Platform) also as part of the Mission to Planet Earth program.

Japan has a strong interest in communications satellites, both as a user and as a potential manufacturer of commercial communications satellites. Over the years, the Japanese have progressed from purchasing satellites built by American companies, to co-developing them with U.S. industry with the ultimate goal of creating their own communications satellite industry.

Communications satellites became a highly controversial area in trade relations between the United States and Japan. In 1989, the U.S. Trade Representative (USTR) filed a "Super 301" trade action against Japan because of alleged unfair trading practices in three areas, one of which was communications satellites. The USTR complaint was that Japan had prohibited procurement of communications satellites from foreign sources if the satellites were for use by the Japanese government or its quasi-private telecommunications agency, NTT.

The specific satellite at issue was the CS-4, intended for both operational and experimental purposes. The United States did not object to Japan procuring experimental satellites from its own suppliers, but insisted that operational satellites be opened for bidding to non-Japanese companies. In 1990, Japan agreed to split the CS-4 program into separate satellites for experimental and operational uses; foreign suppliers will be allowed to bid for building the operational satellites.

Japan experienced setbacks in its use of communications satellites for television broadcasting in 1990 and early 1991. Two Japanese broadcasting satellites were destroyed when an Ariane rocket exploded in February 1990: the BS-2X for Japan's national NHK network, and Superbird B, for Japan's Space Communications Co. (SCC). In April 1991, a U.S. Atlas rocket failed, destroying another satellite (BS-3H), that was to replace an existing satellite which was not working properly because of damage to its solar panels. These losses and failures have created some turmoil in Japan's broadcasting capabilities.

Microgravity materials processing research is also of interest to Japan. This research is currently limited to drop towers and a few sounding rocket flights, but this will change with the launch of dedicated Spacelab missions on the U.S. space shuttle in 1992 and 1994. Also, the Japanese are building a spacecraft (the Space Flyer Unit) planned for launch on an H-2 rocket in 1994 and return to Earth by the U.S. space shuttle after a few months in orbit. Such research also is expected to be conducted on Japan's module for the space station *Freedom* (see below). Japanese officials have complained that Japanese industry has not been enthusiastic about the prospects of microgravity materials

processing, and in 1990, the Ministry of International Trade and Industry (MITI) created the Institute for Unmanned Space Experiments to develop materials processing experiments for the Space Flyer Unit. The Institute is funded by MITI and 13 aerospace companies.

HUMAN SPACEFLIGHT ACTIVITIES

A Japanese journalist, Toyohiro Akiyama, became the first Japanese--and the first journalist--to make a spaceflight. Sponsored by his company, the Tokyo Broadcasting System (TBS), not the Japanese government, he visited the Soviet *Mir* space station in December 1990; TBS reportedly paid the Soviets \$12 million for his flight.

The Japanese government is also interested in human spaceflight activities. Three astronauts have been selected for flights on the U.S. space shuttle during missions dedicated to Japanese materials processing experiments. The first, Spacelab-J or IML-1, is currently scheduled for launch in September 1992; a second is planned for 1994 (IML-2).

On a larger scale, Japan is participating with NASA in the Space Station *Freedom* program by building one of *Freedom*'s four modules (see part 1, chapter 2 for more details on *Freedom*). Mitsubishi Heavy Industries is the prime contractor for building the Japanese Experiment Module (JEM), one section of which will be pressurized, while another section will be open to the space environment. Japan is expected to spend \$2.2 billion for JEM. Like ESA, Japan was dismayed at the downscoping of the *Freedom* program announced in 1991, especially in terms of the number of crew members it can accommodate (four instead of eight). NASA has assured Japan that it will restore the capability to house eight crew members as soon as possible, budgets permitting. In 1990, Japan created the Manned Space Systems Corporation to coordinate industry work on the *Freedom* program. The new company was created by NASDA and 62 major companies and banks, and will focus on supporting NASDA in constructing and operating JEM. Some Japanese officials have expressed anxiety over the lack of planning for utilization of JEM and whether the government will finance the research or expect companies to pay for it.

At one time, the Japanese expressed interest in constructing a "mini-shuttle," smaller than the U.S. space shuttle, but with most of the shuttle's basic features, including reusability, and the ability to carry a crew of four. Subsequently, however, they decided to build an automated vehicle, HOPE, instead that would be launched by the H-2 and carry cargo only, not people. HOPE (H-2 Orbiting Plane) is being designed to support Space Station *Freedom*. The Japanese have initiated studies of an aerospace plane, HIMES, which would be similar to the U.S. NASP (see part 1, chapter 2) and would carry a crew. Japan's National Aerospace Laboratory (NAL) is overseeing the HIMES research program.

COOPERATION WITH THE UNITED STATES AND SOVIET UNION

As already discussed, Japan's space program involves extensive cooperation with the United States beginning with the 1969 agreement that gave them access to U.S. launch vehicle technology and extending to cooperative science and remote sensing missions, and the Space Station *Freedom* program.

The Japanese did not cooperate with the Soviet Union until very recently. Apart from Toyohiro Akiyama's flight to the *Mir* space station (which was not a governmental initiative), Japanese-Soviet space cooperation is still extremely limited.

FUTURE ACTIVITIES

Japan clearly is interested in a broad range of space activities--space science, space applications, human spaceflight--and routinely issues long term plans and government policies asserting its intent to pursue these areas. The most recent *Fundamental Guidelines for Space Policy* was released by the Space Activities Commission in 1989, outlining Japan's overall interest in space activities, its desire for international cooperation, and types of space activities to be pursued through the 1990s.

The programs and goals listed in the *Fundamental Guidelines* are modest compared to frequent press reports about Japan's long range plans. Often mentioned in the press are Japanese "plans" to build space factories, solar power satellites, and lunar bases. These proposals seem to represent more the wishes of space enthusiasts than actual planning by government or industry. While Japan is investing in development of a diverse array of space technologies and a plethora of studies are being conducted, unless the Japanese choose to greatly increase the level of their space funding, it seems unlikely that many of these plans will proceed very quickly.

TABLE 11. Japanese Space Launches

Name	Launch Date	Launch Site	Comments
Osumi Lambda 4S-5	02/11/70	U	Test flight.
Tansei MS-T1	02/16/71	U	Test flight.
Shinsei SS-1	09/28/71	U	Science.
Denpa REX SS-2	08/19/72	U	Launch success, payload failure.
Tansei 2 MS-T2	02/16/74	U	Test flight.
Taiyo SRATS	02/24/75	U	Science.
Kiku ETS 1	09/09/75	T	Test of new N launch vehicle.
Ume ISS	02/29/76	T	Launch success, payload failure (for science).
Tansei 3 MS-T3	02/19/77	U	Engineering test.
Kiku ETS 2	02/23/77	T	First Japanese launch to geostationary orbit; test satellite.
Kyokko (Exos A)	02/04/78	U	Science.
Ume 2	02/16/78	T	Ionospheric sounding.
Jikiken (Exos B)	09/16/78	U	Science.
Ayame 1 (ECS-1)	02/06/79	T	Failed to reach geostationary orbit.
Hakucho (Coraa B)	02/21/79	U	Science.
Tansei IV	02/17/80	U	Test satellite.
Ayame 2 (ECS-2)	02/22/80	T	Failed to reach geostationary orbit.
Kiku-3 (ETS-4)	02/11/81	T	Engineering test.
Hinotori (Astro A)	02/21/81	U	Science.
Himawari 2	08/10/81	T	Weather.
Kiku-4	09/03/82	T	Engineering test.
Sakura (CS-2A)	02/04/83	T	30/20 GHz communications.
Hinotori (Astro B)	02/20/83	U	Science.
Sakura (CS-2B)	08/05/83	T	30/20 GHz communications.
Yuri 2A	01/23/84	T	Operational 30/20 GHz communications.
EXOS C	02/14/84	U	Science.
Himawari 3	08/03/84	T	Weather.

TABLE 11. Japanese Space Launches
(continued)

Name	Launch Date	Launch Site	Comments
Sakigake (MSTS)	01/08/85	U	Halley's Comet probe.
Suisai (Planet A)	08/18/85	U	Halley's Comet probe.
BS2B	02/12/86	T	Communications.
Ajisai; Fuji	08/18/86	T	Test of new H 1 rocket. Ajisai is geodetic satellite; Fuji is for amateur radio.
Ginga (Astro C)			
MOMO (MOS)	02/05/87	U	X-ray astronomy.
ETS-5	02/19/87	T	Ocean remote sensing.
Sakura (CS-3A)	08/27/87	T	Test of H-1 rocket.
Sakura (CS-3B)	02/19/88	T	Communications.
EXOS-D	09/16/88	T	Communications.
GMS-4	02/22/89	U	Scientific satellite (auroral studies).
MUSES-A	09/06/89	T	Weather.
MOS-2; Debut;	01/24/90	U	Lunar test.
JASI-B	02/07/90	T	Ocean sensing plus a test satellite and an amateur radio satellite.
BS3A	08/28/90	T	Communications.

Does not include launches of Japanese satellites by other countries. For launch failures prior to 1977, see *World Wide Space Activities* (House Science and Technology Committee, 1977). p. 203. Prepared by CRS. Launch dates are in Greenwich Mean Time. U = Uchinoura; T = Tanegashima.